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JULY, 1931

SIR JAMES HOPWOOD JEANS IN NEW YORK[1]

GREETINGS OF THE AMERICAN PHYSICAL SOCIETY

By Dr. W. F. G. SWANN

PRESIDENT OF THE AMERICAN PHYSICAL SOCIETY AND DIRECTOR OF THE BARTOL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE

MR. TOASTMASTER, it is my pleasant duty to convey to you, to Sir James Jeans, and to the guests here assembled, the most cordial greetings of the American Physical Society upon this very happy occasion.

There was a time, not very long ago, when, as a physicist, speaking to a group even of such profound mental caliber as I see before me, it would be necessary to explain what kind of beings I represented in my capacity as delegate of the American Physical Society. To the layman the word "physicist" betokened a kind of medical person, and probably a bogus one at that, who avoided prosecution for misrepresenting himself as a physician by calling himself "physicist."

Occasionally, when wandering through life trying to provide a reason for his existence, the physicist would encounter one of those nervous, haggard people of the type whose individuals are trying to "find" themselves, usually one of those very serious beings with a thirst for knowledge and the higher things of life. And she would say, "Ah, you are a scientist. I suppose you look at bugs under a microscope." And she would look at you in a manner which implied that she regarded you almost as a personal friend of the bugs. You hastened to tell her that you did not look at bugs under a microscope but devoted your activities to quite other pursuits. "Ah," she would say, "then you invent things. Do tell me of your inventions. What are you inventing now?" Then you had to say that you did not invent things—what you did was to seek the unknown, fathom the unfathomable, explain the inexplicable, and, as the darky preacher put it, "unscrew the inscrutable." You would say that your function was to expand the boundaries of knowledge—push back the horizon of discovery, and search for the hidden mysteries of nature for the benefit of the world and the good of mankind. And while you were saying all this, you became conscious of a look in her face amounting to a strong suspicion that you really didn't do anything at all which amounted to anything, and that you were just a great, big bluff trying to wiggle out of an embarrassing situation. Then, alas, as a physicist you envied the power vouchsafed to so many in other fields of learning—the power of oratory—the power to say nothing with force and conviction.

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[1] Addresses at a dinner given in honor of Sir James Hopwood Jeans on May 28, by: The New York Museum of Science and Industry, The American Institute, The American Museum of Natural History, The Amateur Astronomers Association, The New York Academy of Sciences and The Scientific Monthly. Sir James's address was broadcast by the National Broadcasting Company.

Now the engineer, such as our toastmaster, was in a much happier situation. Everybody knew what he did. Your impecunious solemnity contrasted poorly with his prosperous joviality. He simply bristled with prosperity; and, even in the pleasures of life, he did not seem to be limited to the one-half-of-one-per-cent. variety of iniquity which you enjoyed. If you doubted that he did anything, he could point to a locomotive and say, "See, I made that." He could point to a radio and say, "See, I did that." Of course, the poor physicist might plead that he had a small hand in the radio, too. "Oh, yes, poor fellow," one can imagine the engineer saying, "we do have a few of them in our employ."

This reminds me of a story. (Most after-dinner speakers are reminded of a story at the beginning, but some time or other you have to be reminded of it. It seems so much more natural to be reminded of it than to think it out beforehand, and so I am reminded of a story.)

Many years ago, when I was a youngster just through with college, I decided that I ought to know more about the practical things of science, so I went to take a course in electrical engineering. I felt that I wanted to learn really how big 1,000 amperes was. Of course, I could calculate things about 1,000 amperes, but I did not feel that I really had a personal acquaintance with it. I did not know whether I was justified in feeling that I was very noble and self-sacrificing in putting down the switch carrying it, or whether I should take out special insurance, or even say "good-bye" to my family.

So I took the course in electrical engineering. My partner in the laboratory was an old friend of my schoolboy days, an Irishman, wonderfully good-natured, but endowed with an uncontrollable desire to embarrass anybody who seemed susceptible to embarrassment. Some of the first work in that course concerned pure physics. Now I knew a lot about that, having just confounded all my examiners in their efforts to belittle and crush me in my praiseworthy ambition to secure the degree which I had just obtained. So I knew quite a lot of physics. As a matter of fact, I knew more physics than those junior instructors who looked after us in the engineering laboratory, and my friend, the Irishman, knew that, so he would come to me with all sorts of questions regarding the origin and significance of rather complicated and more or less empirical formulae which were used in the course. On the basis of the information thus gained he would proceed to seek out some of the junior instructors who had annoyed him in some way or other, and ask them very awkward questions about the formulae, much to their embarrassment and discomfiture. This, of course, did not increase our popularity in the laboratory. However, that was beside the point. One day we were assigned to work on a centrifugal pump. Now it so happened that in my work in physics I had had occasion to experiment upon very fine jets of water about a millimeter wide; but it was a terribly long stretch from these jets to the nozzle of that centrifugal pump. Never before had I seen such a "beast" at close range. I became very humble in its presence. After checking up very carefully all the electrical connections and getting the Irishman to stand guard in case anything should happen, I hastily put down the switch and pulled it off again. The laboratory was still there, the universe went on its course, unconcerned, so I summoned up my courage, put the switch down again and left it down. The pump proceeded to roar and made an awful, angry noise, but it didn't deliver any water. Of course, I was horrified. I felt certain that we must have done something wrong and that we had probably "busted" the pump. Then, while we were meditating in sorrow, around came one of the junior instructors aforesaid. We bewailed our misfortune to him; his answer was, "But did you charge the pump?" Of course, we had not charged the pump. Whoever would have thought of subjecting the pump to such an indignity? However, he assured us that the pump would not mind, and pointed out a funny little opening, covered by a cap, near the top, where the water was supposed to be poured in. Well, of course, we felt rather foolish, so I decided we wouldn't make any mistake like that again. We would go slowly, step by step. We would start the motor first. Then we would slowly pour a little water into that opening at the top, and as the pump got gradually going, we would close that opening and let everything develop harmoniously. So I sent the Irishman up the ladder to the opening, (it seemed to me in every way appropriate that he should be the one to go up), and we proceeded according to our plan. Now no sooner did that pump taste the water that the Irishman poured down its throat than it set up a terrible furor, shot up a jet of water which drenched the Irishman and nearly knocked him off the ladder, and then proceeded to deliver from the business end a torrent of water such as I had never dreamed of. Well, of course, there was a great commotion and an awful mess on the floor—oil and water and everything. Then the head of the laboratory came around. I tried to look dignified, but it is very difficult to look dignified in the face of a mess of oil on the floor when you have been responsible for it. The head of the laboratory proceeded to "call us over the coals," but he stuttered very badly. (You know, I think it is one of the most embarrassing things in the world to be "called over the coals" by some one who stutters. You can not possibly help him out. It doesn't seem dignified to help him out, and you just have to stand still and wait until he has had his say, with the consciousness that the enforced periods of silence during his utterances also meant something very terrible, if only it could be expressed.)

Yes, even in those days, there was quite a difference between the materialism of the engineer and the asceticism of the pure physicist—the word "pure" not being intended to imply any moral turpitude on the part of other kinds of physicists—but to-day the physicist has delved into a realm of abstractness in which he views almost with a pitying tolerance the efforts of his predecessors to realize a concrete mechanistic structure. He sees them striving to invent a medium to pervade all space, a medium which could propagate light and heat and wireless waves—a medium in whose subtle properties it was hoped to find the explanation of gravitation and of everything else which needed an explanation in the universe. They would have liked to think of a medium such as water, but water would not do, because the kind of waves which water would transmit are quite unsuitable for light. An elastic solid would have been much better for light. But how could the earth and all the planets move freely through a solid? And so there was much puzzling of brains to imagine how a medium could act on the one hand like the most limpid of fluids, and, on the other, like the most elastic of solids. The mathematical theory defined precisely the properties of the desired medium, the ether, but the mathematical equations looked cold and lifeless. There was nothing else in the universe which seemed anything like what this medium had to be; and, the grayer your hairs, the less you liked it. What was this mysterious medium? I believe it was Lord Salisbury who defined the ether as "a word designed to provide a nominative case for the verb 'to undulate.'" A little while ago, I gave another definition of the ether, a definition designed to call attention to the attitude of mind of one who spends too much energy in an endeavor to see a materialistic explanation of everything. And so I have ventured to define the ether as "a medium invented by man for the purpose of propagating his misconceptions from one place to another. Of all subtle fluids invented for the stimulation of the imagination it is the only one which has so far not been prohibited."

After all, the abstract point of view in science is not so bad when one gets accustomed to it, and particularly when one realizes that most of the things which catch the eye of the mind in pictures and theories most immediately palatable are often irrelevant to the purposes in hand. I have often meditated upon what I have called "the irrelevance of the obvious." I think of myself setting a problem to a little boy. The problem concerns a ball thrown upwards with a given velocity, and I ask him to calculate the time taken by the ball in reaching its highest point. He comes to me and complains that I have not given him enough information. I ask him what information he needs. He tells me he would like to know the color of the ball. I tell him that the color does not matter; but he may not like that, because a certain amount of the substantiality of the ball has vanished with its color. He asks for the weight of the ball, and I tell him that that doesn't matter, and I add to his troubles by telling him that I will withdraw even my remark that it was a ball, and leave its shape indefinite. Then, if he is over-materialistically minded, he will explode entirely and demand to know how he is to work out any problem about the body if I won't tell him its color, shape or mass. There is nothing left for him to think about, and he may well claim that it is difficult for the human mind to think at all unless it has something to think about. Well, to please him, I tell him the body is red, weighs ten pounds and is really a round ball. Now he is happy. He takes his paper and pencil, draws the round ball, puts a 10 inside it, paints it red in his mind's eye and works out the problem. When he brings me the result, I inquire at what point the redness of the ball came into his calculations. He looks through them and finds it didn't come in at all. The result would have been the same for a blue ball. Then I ask him where the 10 pounds came in. He looks again and finds he did not use it; or, if he did, it cancelled out, so that the result would have been the same for a fifty-pound ball. Finally, I ask him where the roundness came in, and he finds he did not use that at all. So I say to him, "Don't ask me for a lot of unnecessary things again." But I think I hear you sympathizing with the poor student. "What harm," you say, "did the redness of the ball do? Why did he sin in thinking it was ten pounds in weight and that it was round if, after all, these things did not matter?" Well, I agree that in this particular case the redness did no harm. But I suspect that if I let the student think the ball is red he will come to me some day with some ideas founded purely upon the redness of the ball. He will be troubled, because he will want some other ball to do the same sort of thing that this ball did, and will be unable to satisfy himself because, perchance, the second ball is blue. Then I shall have to go to the trouble of raking up past history to show that the redness did not matter; but, if he has enjoyed the vision of redness for a long time, his whole mental equilibrium may be destroyed if I take it away.

An archdeacon has been defined as "one who performs archdeaconal functions." Sometimes we laugh at that definition; but, provided the functions are expressed explicitly, it is a very good definition—a much better definition, for example, than one which defines the individual in question as "one who wears gaiters and a top hat of rather ostentatious shape." It is true that the gaiters and the top hat are the most immediately obvious features of the archdeacon, but one who riveted his attention on these appendages as the most fundamental attributes of an archdeacon might be at a loss to understand the significance of the individual if for some reason he were without them, in spite of the fact that he might be just as good an archdeacon. The obvious part of the archdeacon is irrelevant to his true functions. So in science we encounter many instances where we choose to think of things mainly in terms of their activities, and we are loath to add to them appendages which may hinder or complicate those activities.

He who encumbers himself too much with the débris of irrelevant concepts is apt to build up for himself a confusion of troubles. He may have his ether with safety so long as he does not worry himself as to its boiling point or as to the question of whether or not it should freeze in the cold of interstellar space, and whether there should be icebergs of ether floating about. Analogy is all right so long as it is not distorted; for, in distorting it, we are like the dramatic person who, speaking of certain evils in his community, remarked: "The insidious influences are like a melting stream of warm water eating slowly but surely into the heart of an iceberg, burrowing on and on until they finally eat out the very center of gravity itself, causing the whole iceberg to turn turtle and dive to the bottom of the sea."

Physicists the world over recognize in our guest of honor not only a great astronomer, physicist and thinker, but one who has done much by his writings to guide the layman through those tortuous paths of modern thought to such realization as is possible to the nontechnical mind, of the modern point of view. To the layman he has acted as a catalyst of thought. For the benefit of those who do not know what a "catalyst" is, I must close by being reminded of a story:

There was an Arab who died, leaving all his worldly goods to be divided among his three sons—the first to receive one half, the second one a third, and the third one ninth. But his possessions were found to consist of seventeen camels. And when they came to make the division, they saw not how the seventeen camels could be divided, so they went in perplexity to the sheik. And the sheik, after deep thought, spoke thus: "My sons! Thy father was a great friend of mine, and though I am a poor man and have but one camel, for thy father's sake I will donate him to thy service that there may be no dissension among ye." So he added his own camel. And then he said to the first son, "Thy father gave thee one half of his worldly goods, but I give thee nine camels, half of eighteen, which is more than thy lot. Go thou and be content." And he said to the second son, "Thy father gave thee one third of his goods, "but I give thee six camels—one third of eighteen—which is more than thy lot. Go thou and be content." And he said to the third son, "Thy father gave thee one ninth of his goods, but I give thee two camels, which is more than thy lot. Go thou also and be content." And then he counted up the camels he had allotted them, "nine and six are fifteen and two are seventeen," and there yet remained his own camel, which he took back once more, saying, "Lo, I have given each man more than his lot, and I get back my own camel. Blessed be Allah."—That eighteenth camel was a catalyst.

INTRODUCTORY REMARKS

By Dr. MICHAEL I. PUPIN
PROFESSOR OF ELECTRO-MECHANICS, COLUMBIA UNIVERSITY

OUR guest of honor is an old friend of many of us. We learned to know him and to love him over twenty-five years ago when he was a young professor of mathematical physics at Princeton College. He was then a handsome English youth, and he is that still; successful intellectual efforts are obviously a wonderful preservative of physical beauty, especially when they result in four best sellers in four consecutive years.

I remember how glad we members of the American Physical Society were to see this quiet and unassuming Cambridge mathematician at our meetings, and how we missed him when his attendance began to show a rapid fading. Rumor had it that this shy Cambridge youth had suddenly grown sufficiently bold to court a bright and beautiful Connecticut lassie, that he had proposed, and that she had accepted him. The rumor proved to be true, and I said to myself: A Connecticut lassie knows a good thing when she sees it. The Connecticut lassie is Lady Jeans to-day.

That delightful romance of twenty-four years ago was the turning point in the brilliant career of our guest of honor. If it had not been for that romance he might still be a professor at Princeton College, pouring in daytime Newtonian philosophy into reluctant undergraduate heads, and wasting his precious evenings criticizing dull examination papers. But Jeans, the happy bridegroom, aimed higher than Jeans, the humble bachelor. He soon resigned his professorship at Princeton and returned to his old university where, during his Trinity College days, he had gathered many laurels in the fields of Newtonian philosophy. Soon after his return to Cambridge his American friends, including myself, were thrilled by the brilliant essay which he published in 1914. It was entitled "Radiation and the Quantum Theory." Several other essays of similar character followed in rapid succession, and they revealed what to his old American friends looked like a miracle. He, a most ardent disciple of the venerable Newtonian school of historic Cambridge, had become an inspired apostle of New Physics, first inaugurated by Planck and Einstein in the beginning of this century. This miracle reminded them of the miracle of St. Paul's sudden conversion on the road to Damascus. At that time Planck was an humble German professor, and he is that still; Einstein was a clerk in the patent office of Switzerland. New Physics, the great science of to-day, had humble beginnings.

Planck's Quantum Radiation and Einstein's Relativity Theory are the two foundation pillars of New Physics. Our guest of honor believes that no one except a mathematician need ever hope to understand fully their endeavors to unravel the fundamental nature of the universe. Knowing that there are not many mathematicians in this distinguished gathering I shall not proceed any further in that direction. One application, however, of these endeavors makes the writings of our guest of honor so illuminating that I can not allow this occasion to pass without a brief reference to it.

According to New Physics radiation of heat and light by the luminous stars pours out the substance of these stars into the interstellar space. The mass of the stars diminishes and that of the interstellar space increases. Just as gravitation means concentration of cosmic substances into stellar centers, so radiation means their diffusion from these centers into the interstellar space. This mass diffusion by radiation, astronomy tells us, is millions of millions of years old. It has been kept alive, according to a brilliant suggestion of our guest of honor, by the transformation of atomic mass into radiation mass. He calls this process atomic annihilation, and traces its origin to the coalescence of the electrons and protons of the atoms in the stars as well as in the interstellar space, and to the transformation of the intrinsic energy of these atoms into the energy of photons, Planck's indivisible wave granules of radiant energy. The final result, which interests us human beings, is the flooding of the interstellar space with stellar torrents of photons of all possible wave-lengths, from the vanishingly short wave-lengths of the cosmic rays to the much longer wave-lengths of the rays which supply light and heat to our terrestrial globe. This picture, painted so well in the writings of our guest of honor, suggests to my mind the following thought which you will kindly permit me to mention here.

Each one of that practically infinite variety of photons seems destined to perform a definite service to the living world. Every blade of grass and every tiny flower on our meadows and pasture lands, every leaf of our forests and every gay flower of our honey-hearted gardens, can tell a wonderful story of that service. Nay, every microscopic and ultra-microscopic granule in the nuclei of our bodily cells will, perhaps, some day tell a secret tale of the service rendered by the cosmic rays to these tiny structures which are destined to provide a housing for the living soul of man. Whether those mighty streams of photons, speeding with the velocity of light from the countless billions of the blazing stars into the interstellar space, are hastening to perform some other useful service in some other hidden corner of the universe science can not tell. Science can not penetrate the mysterious veil which covers the face of the space-time entity, separating the world of ultimate reality from the world presented to our senses and interpreted by mere pictures of mathematical symbols. Faith alone penetrates it and finds behind it the throne of the divinity which created that space-time entity and filled it with electrons and protons, and with their offspring, the omnipresent photons, the tiniest and liveliest energy granules in the ever-expanding interstellar space. One can not resist the hope that some day, perhaps, we might discover that these ultra-refined energy granules are responsible for the first beginning of life and for its never-ending evolution.

These are some of the thoughts suggested to my mind by the brilliant writings of our guest of honor, Sir James Hopwood Jeans.

MODERN THEORIES OF THE UNIVERSE

By Sir JAMES HOPWOOD JEANS, KT., D.Sc., LL.D., F.R.S.

DORKING, ENGLAND

Owing to a happy inspiration on the part of those who arranged the dinner I am not called on to make an ordinary after-dinner speech of the conventional type. I have been asked to speak about the advance of science in the last few years. At the same time, I am sure I shall not be doing wrong if I take one or two minutes of my time to thank the toastmaster, my old friend, Dr. Pupin, for his very kind and very generous introduction, and to thank Dr. Swann for his message from the Physical Society; and to thank you all for the very cordial reception which you have given me and which has touched me so deeply.

It was, I think, inevitable, when I was asked to choose a subject to-night that I should think at once of the contrast between the science of to-day and that of twenty-five years ago, when I was here teaching in your country. Let me, however, turn my thoughts and your thoughts back a little bit further than that. Let us go something like fifty years back into the age of mid-Victorian materialism. We find that science did not then contemplate the universe at all. Science could be compared then to a series of roads which diverged out in different directions—physics in one direction, chemistry in another, astronomy in a third and so on. All these roads radiated out from a center, which was, in brief, our noble selves.

We took mankind, so to speak, to be the center from which science worked. Astronomy moved out a certain distance —a very small distance as we now know—from our home in space and explored the near neighborhood of our own little planet. Physics tried to discover what it could about Nature and matter, but it was never able to get down to the small ultimate fabric of the universe. The particles of which matter was built were too small for examination in those days. We could only examine particles which were of such a size as could be seen by our human eyes or by optical aids fashioned by human hands. And so it was all along the line.

As a result of that it was inevitable that we should think of the universe as being something like the material tool, so to speak, with which we examined it. In the ordinary events of everyday life such as were then studied, we found that bodies moved as they were pushed or pulled. The simplest physical experiment was one performed with our muscles—let us say, lifting a weight. We found that all the objects around us acted as though they were pushed or pulled by force similar to those of our muscles. And the physicist of those days created for himself a universe in which he imagined that however far one went along any one of these roads, he found bodies, substances, which acted simply in accordance with the pushes and pulls which were exerted on them. He thought, in other words, of the universe as a purely mechanical structure.

Then came ten wonderful years, five years at the end of the last century, and five years at the beginning of this—the years 1896 to 1905. When the history of science comes to be written in its proper perspective by one remote descendant, it will, I think, be found that those ten years rank at least as high as any ten years in the past history of science. The discoveries of those ten years will stand at least as high as the discoveries of the ten wonderful years starting with 1609, when Galileo first explained to men how to work the telescope, and so discovered a new structure of the heavens. They will stand as high, I think, as the discoveries of those wonderful years which began with Newton's work while he was still an undergraduate at my own college of Trinity College, Cambridge, and ended by his announcing the law of gravitation and proving that the universe was subject to universal laws.

To the ordinary man, I suppose, those ten years are generally regarded as the ten years in which physics became unintelligible. The picture that he had drawn for himself of the universe around us became replaced by what Dr. Swann has described as the heartless and cold-blooded formulae of mathematics. But to scientists, those ten years meant very much more than that. To the scientist, and to a lesser degree the ordinary man, they represent the epoch in which science assumed a new aspect of thrilling interest, in which we first began to contemplate the universe as a whole, and in which instead of thinking of science as a few roads diverging out from our own circle, we rather began to think of it as a whole lot of roads converging on one central point and leading to an understanding of the universe as a whole.

Let me remind you of the tremendous discoveries of those ten years, discoveries of which we haven't yet seen the full implications.

The first two or three of those years saw the electron isolated, and resulted in our discovering that it had a definite structure. We began to think of it almost as a universe in itself and no longer as a sort of hard particle which had been left to us from the times of Democritus and Lucretius. In those same years radio-activity was discovered, and that perhaps more than anything else has helped us unravel the mysteries of the atom and the innermost structure of the material of which the universe is built.

Then with the turn of the century in 1900, the quantum theory was introduced by the genius of Professor Planck, of Berlin. We still haven't seen the full implications of that either, but it has, at least for the time, abolished determinism from physics. No one can say whether it will be restored or not; but at least it has put before us a picture of a universe which is governed by something entirely different from the hard-and-fast mechanical laws which our Victorian ancestors imagined.

Then—at the end of the ten years—came Einstein with his theory of relativity. This took away the material basis on which we had worked for so long, and through that more than anything else, perhaps, the study of physics became unintelligible to the ordinary man, and of thrilling interest to the scientist—as also to the philosopher.

Throughout those ten years another phenomenon was emerging, cosmic radiation, of which we haven't yet got to the bottom. These cosmic rays come to us as messengers from the first depths of space, and their message, as far as we can read it, seems to be that the physics and chemistry that we study on earth are only tiny fringes of enormously vaster subjects. The physics and chemistry of space seem to be something wider and bigger than anything we have yet imagined, and these cosmic rays come to us to tell us of conditions prevailing in outer space.

All those subjects which I have touched on have their foundations in research which was carried on by hard-working scientists in that single decade that I have mentioned. Only now we are beginning to suspect the full implications of those discoveries. And yet, little though we know, I think it is fair to say that by now science has in a sense surveyed the universe from one end to the other, from the largest objects known in it, the great spiral nebulae, down to the smallest objects, electrons and protons. We believe there is nothing larger than the spiral nebulae, except the whole universe itself, and, as far as we know, there is nothing smaller than the electron which has a permanent existence as a physical structure.

And now whichever way we look at the universe, an extraordinary phenomenon emerges. We find we can no longer interpret the universe, either in its smallest or its greatest aspects, as a sort of mechanical phenomenon, in the way in which our mid-Victorian ancestors would have interpreted it. We look at one end, the thing smallest we know, the electron, and we find that this must be regarded not merely as a hard particle, or merely as a charge of electricity, but rather as what the physicists describe as a wave packet. If we want to compare it to something, we must not compare it to a material object, but rather to something of the nature of a storm at sea, a collection of waves which move in certain ways and by the way they move determine the whole phenomena of gross matter. The materialist at once asks: "Waves in what?" And the answer we have to give is—waves in nothing at all, because there is nothing left in science in which waves can undulate, to use Professor Swann's term. The ether being abolished by the theory of relativity, everything we know with any capacity for undulation has disappeared, and the waves must be regarded purely as mathematical waves. They are, so to speak, descriptive rather than a material phenomenon. We can express those waves by mathematical equations, but if we try to go beyond that and express them as waves of something material, we are at once led into a tangle of absurdities and contradictions.

It is much the same with electricity itself. We must now think of electricity simply in terms, I believe, of mathematical formulae. Last Sunday I read in *The New York Times* a verbatim translation of Professor Einstein's lecture. As might be expected, he did the best that any man could do to explain the nature of electricity, or his present views on it; and yet, as I read it, I wondered to how many readers what he said would be at all comprehensible. It is probably safe to say that no one who is not a trained mathematician could take very much out of that lecture. They couldn't, at least, follow Professor Einstein's thought in the way in which it deserved to be followed.

We used to think of all natural phenomena as a result of forces. Einstein has abolished force from Nature. We no longer believe there is any such thing as force. Particles and larger objects simply follow paths, which are determined by something different than force. They are determined by the curvature of space, and when we try to inquire what this curvature of space means, no one except a mathematician can really answer the question; and when a mathematician does answer it, no one except another mathematician can understand it.

When we look at the other end of the universe, with our astronomy of the last few years we have discovered that space is something enormously greater than we ever thought it to be. We used to in the past think of space as the solar system and a little bit outside it. We know now that the solar system is about as one grain of sand in the universe compared with all the sand on all the seashores in the world.

It is the same with time. We used to think of time as extending through the whole of human history and perhaps a little bit beyond. We now think of time as something so immense that all human history is only the twinkling of an eye. We can take a postage stamp and represent by the thickness on that postage stamp the whole of recorded human history. We can stick that postage stamp on the top of the Chrysler Building, and the Chrysler Building will not be high enough to represent the rest of astronomical time.

And yet, the most surprising discovery has not been that space and time is so vast. It has rather been that they are finite, and limited in all directions. We can't go on through space forever. If we do, we just come back. We can't go on through time forever. If we go in one direction, we come to something which is called the beginning, although we don't know what that means; and if we go in the other direction, we probably come to something which may be called an end, although we don't know what that means.

And again, the average man who is not a mathematician can't properly realize or visualize what we mean by finite space or by finite time. They come out nicely in a mathematical formula, but as soon as you try to draw a picture of either, you are done for. They are not things which permit of material representation in any form whatever.

Any one who has lectured on these subjects or written on them is accustomed to getting letters by the basketful telling them that they are talking nonsense. People say space can't be finite because outside it can't be anything but more space. If you say space is finite, your correspondents tell you it simply shows you don't know what you are talking about. Well, the answer, of course, is that all these good people are trying to make material representations of space and that space does not permit of this. As soon as one thinks of space as a mathematical concept, or even as a mere concept without mathematics, finite space becomes intelligible. It is like the finite space of one's thoughts. One can think of New York without thinking of the whole of the United States, and one can speak of the space in New York without being told it is an absurdity, because there must be space outside.

Then space as a thought, as a mental concept, is intelligible and satisfying, and from that concept in the way in which it is treated by Einstein, all these phenomena—gravitation, electrical forces, etc.—seem capable of emerging. But if once we try to picture space as something concrete or material, we simply can't answer the objections of these people who write and say it is absurd to talk about finite space because there must be more space outside.

The same difficulty comes up in a more acute form in respect of a newly discovered phenomenon—the expansion of the universe. These great nebulae now appear to be receding from us with terrific speeds in all directions. The simplest explanation, and one which has mathematical support, is that space is not only finite, but is continually expanding. Space itself is getting larger and larger. The person who tries to make a concrete picture of this, of course, objects at once that space can't get larger and larger if there is nothing but space to expand and eat up as it increases except more space. So long as we think in concrete terms, that argument is pretty well unanswerable. The answer to it is that we must not think of space in those concrete terms. We must think of space as a mathematical concept as a mental concept, such as the mathematician is familiar with, and such as he handles every day.

It is the same throughout the whole of astronomy with the universe as a whole. It is the same throughout those parts of physics which deal with the smallest particles of matter. None of the concepts which we come upon can be pictured in material terms. Always we come to concepts which mathematics and its symbolism can explain admirably, but which the concepts and the terminology of the engineer fail completely to explain. If we think of the universe in terms of mathematics, in terms of pure thought, or in terms of mental concepts, it becomes comprehensible. If we think of it as a piece of machinery, as we used to, an ocean of machinery spread out around us in the ether, extending in all directions and acting by its pushes and pulls, it not only becomes incomprehensible, but when we try to discuss it or argue about it, it leads us into an absolute morass of contradictions and inconsistencies.

Such in brief, as it appears to me, is the change which has come over physics in the last few years, even in the time in which we ourselves have been working in physics. The philosophical implications are, of course, tremendous. They remain to be worked out, and it will be a long time, I think, before the last word has been said. What I wish to suggest to you and try to picture to you in the few minutes which have been at my disposal has been the tremendous change which has come over our most fundamental and innermost ideas as to the structure of the universe. We must no longer think of it as a great, elaborate piece of machinery crushing us by its weight, but rather as a universe of thought, which can only be understood if we approach it by thought, and in particular, by that particular kind of thought which we describe as mathematical.

THE DEVELOPMENT OF THE EGG AS SEEN BY THE PHYSIOLOGIST[1]

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IN the preceding lecture[2] our attention was called to the intrinsic or innate potentialities of the fertilized ovum as it starts out on its career for better or for worse. Its capacity to grow is determined when the egg or maternal gamete and the sperm or paternal gamete fuse. While the new individual has inherited limitations by virtue of which an oyster egg, for example, need not aspire to be a fish, nor one of my monkey eggs a man, it yet devolves upon the maternal parent, from the lowest species to the highest, to place the egg in the environment best calculated to favor the development of the offspring. Thus, butterflies lay their eggs upon the favorite species of plant. Fishes and Amphibia exhibit elaborate behavior patterns for mating and for the care and protection of their offspring; indeed, the more one studies these lowly vertebrates the more respect one has for the denizens of the waters in comparison with the much adored birds, denizens of the air. That birds are more marveled at in the variety of their reproductive instincts—migration, courtship, song, nest-building—while fish are just "poor fish," is just another example of beauty passing for brains. For fish too have courting colors of brilliant hues, build nests and defend them and their eggs and young with great courage—complex activities, all under the stimulus of internal physiological processes that have to do with reproduction, in the possession of which birds do not surpass fish, and both, in some respects, equal the mammals.

These examples are cited to show that the whole chain of endocrine glands that we know in mammals and man are already functional in the lower vertebrates. Indeed, in all classes of backboned animals except the birds there occurs here and there the intra-uterine form of gestation, sometimes, though erroneously, considered a mammalian character. When Joan Lowell writes in her notorious "Cradle of the Deep" that she "learned about women from the shark" she indicated a biological truism, for sharks do have as complete and intimate a union of mother and fetus as exists, for example, between the unborn calf and its mother. We may, indeed, generalize to the extent of saying that there is nothing about the reproductive process in man and mammals that is not foreshadowed in the so-called lower classes mentioned. One may in fact affirm with confidence that fundamental discoveries in the field of reproduction, even as applied to the human species, will be made by studying the lower forms: the salamander, the pigeon, the lowly guinea-pig. In this lecture, however, especially since we are working on mammals, particularly monkeys, which after all come closer to man, we shall speak about the mammalian egg, and trace its behavior from conception to birth.

From the title one might suppose that the intrinsic physical and chemical factors of development were to be discussed. But of internal protoplasmic drives, adjustments, regulators, we know only from the study of amphibian and invertebrate eggs. Instead, the present lecture is a kind of prosaic "Aeneid" that relates, in an un-literary way, the origin, the wanderings, the dangers and vicissitudes that beset the microscopic hero, not on unfriendly shores and the Stygian darkness of the hereafter, but in the once mysterious darkness of the ovary, the oviduct and the womb. The hormones as guardian angels preparing the way and guarding the temporary domiciles will loom large in the story. The egg will be traced as a microscopic traveler from its beginnings, where it is more or less passive, through its development, where it later makes itself felt and is the center of far-reaching interactions with the mother harboring it for so long a time. For pregnancy involves profound changes in the female organism which are only beginning to be understood. The egg, by which is understood also the embryo or fetus with its envelopes and placenta, forms the center from which emanate stimuli that initiate changes calculated to maintain the life of the new individual in the making. The nervous element steps into the background, the glands of internal secretion come to the fore.

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[1] From a symposium on development given at the Carnegie Institution of Washington in November, 1930.

[2] Dr. George L. Streeter, "The Development of the Egg as seen by the Embryologist," SCI. MO., June, 1931.

Of the glands sketched in black in Fig. 1, the ovaries and the hypophysis, more particularly the anterior lobe, are of prime importance. The thyroid and the hypophysis are intimately linked in mutual association, for when one is interfered with the other languishes. Pineal and thymus have to do with sexual maturity and the cortex of the adrenals has some relation, poorly understood, with its twin in embryonic development, the ovary or the testis. The parathyroid has to do with calcium metabolism and so does the ovary. With the changing metabolism of pregnancy the pancreas and the liver become involved. On the whole, however, for the present purpose we may dismiss from consideration, as having no very specific effect on the fate of the fertilized egg, all the endocrine glands except the ovaries and the anterior lobe of the hypophysis. Even the posterior lobe of the latter, source of the far-famed and much-abused pituitrin, artificial birth initiator, has probably nothing to do with spontaneous normal birth at term. Uterus, placenta and embryo may possibly also function in an incretory way during pregnancy.

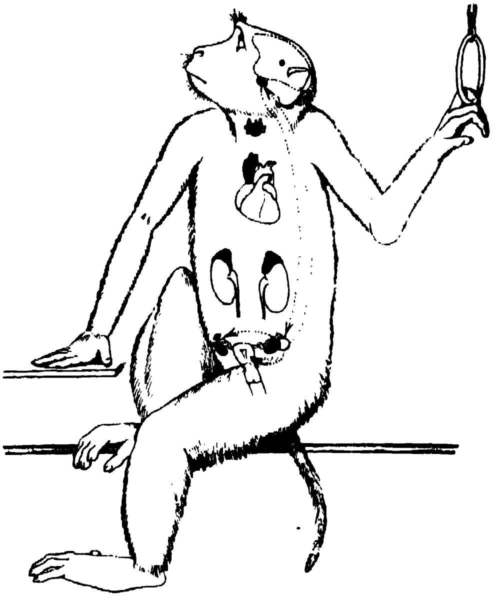


FIG. 1. OUTLINE OF FEMALE MONKEY WITH SOME OF THE ENDOCRINE GLANDS DRAWN IN BLACK. THE ARROWS INDICATE THE RECIPROCAL RELATIONSHIPS AMONG THE GLANDS, AND THE ORGANS MORE DIRECTLY AFFECTED BY THEM.

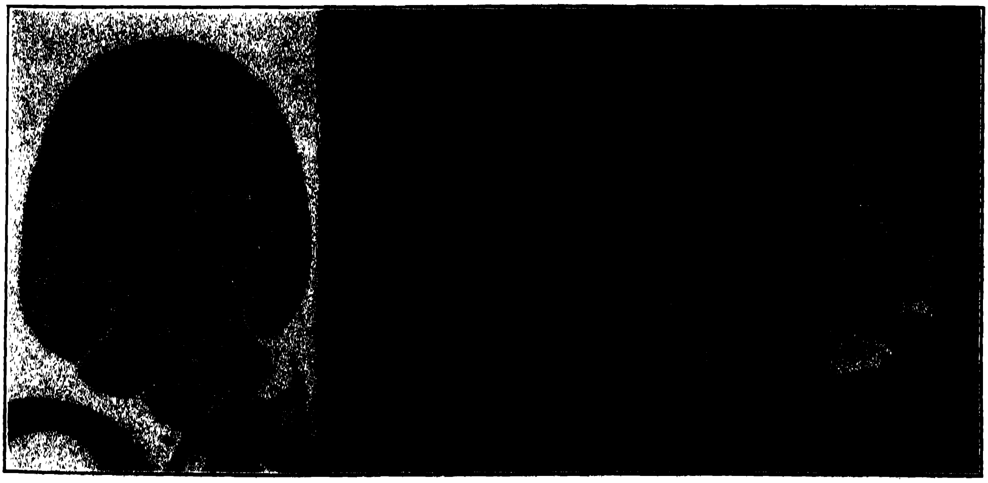
In this brief hour, therefore, we shall follow the fortunes of the egg as this reacts with the ovaries and the anterior lobe and we shall consider the revolution which the egg in its turn stirs up while it reigns as the *primum movens*, during its sojourn within the mother's body. In this way we may lay more emphasis upon the anterior lobe than this deserves, because the ideas are new and now have a vogue. But certainly the newer ideas are based upon more experimental evidence than the ancient theory that the gland is the seat of the soul! We do know definitely that it is the mighty regulator of the reproductive organs.

Since the dictum *omne vivum ex ovo* is as true to-day as a hundred years ago, let us begin by considering the origin of the eggs. As the ovary develops in the female fetus *in utero*, showers of eggs (Fig. 2) multiplying by successive divisions, grow down from the surface of the ovary and invade the depths of the organ, to arrange themselves later as independent structures, wrapped in a single sheet of the thinnest nurse cells. At birth a girl possesses 100,000 to 500,000 such eggs in her ovaries. Of these she needs at best one every moon or not over 500 from 13 to 53 years of age; hence the vast majority are doomed to destruction without even being shed. This degeneration and resorption goes on from birth to the menopause and constitutes a continuous bombardment of the female organism with hormones. The resorbed substances may be the ones that make the female what she is according to the dictum: *mulier est quod ovarium est*—a woman is what her ovaries make her.

The prodigality of nature as to the production of eggs in mammals is even greater than just stated according to those who hold, with some reason, that throughout the reproductive period of life the production of new eggs proceeds without interruption and *ad infinitum*. In spawning fish there is no greater chance for operation of the law of survival of the fittest than in the mammalian ovary.

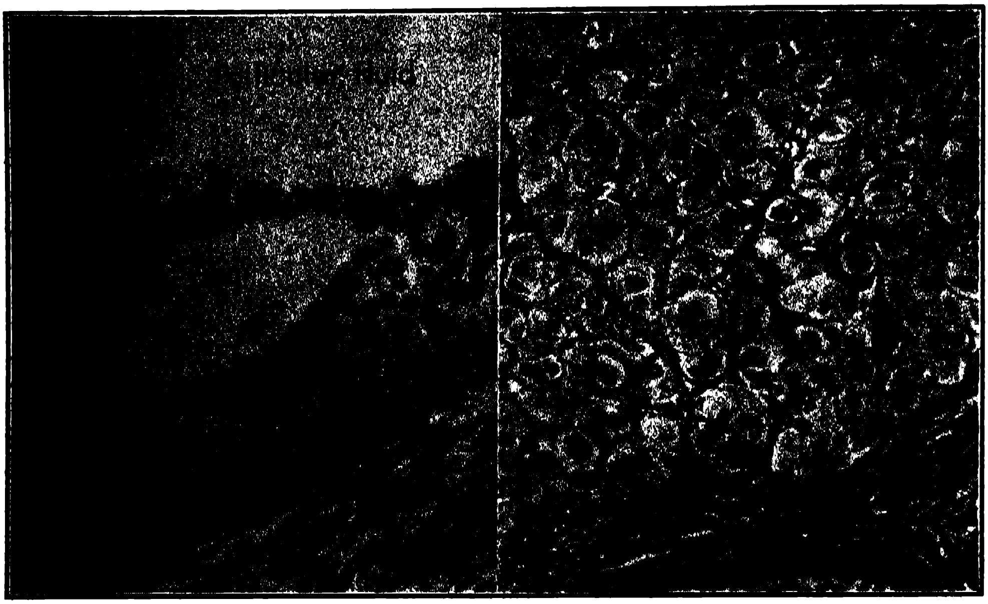
At puberty a change takes place, not suddenly but nevertheless profoundly. The ovarian follicles grow larger, the internal secretion of the ovaries more intense. It now appears that in these changes the direct factor is the anterior lobe, for it is possible, by injection of extracts or transplantation of the gland substance itself, to bring a baby mouse or a baby monkey to "maturity" in a few days' time. The ovary is directly affected by the anterior lobe hormone and responds by the swelling of one or more follicles, usually only one in man and monkey, in the manner now to be detailed and illustrated.

Let us, then, visualize the growth of



FIGS. 2 TO 4. OPOSSUM OVARIES

FIG. 2. MICROSCOPIC SECTION THROUGH THE OVARY OF A POUCH YOUNG, 23 DAYS OLD. THE ORGAN IS SOLIDLY FILLED WITH EGGS. FIG. 3. TWO HALVES OF OVARIES CUT IN TWO TO SHOW IN EACH SEVERAL LARGE FLUID-FILLED GRAAFIAN FOLLICLES. FIG. 4. OVARY CUT IN HALF TO SHOW THE SOLID CORPORA LUTEA. THE KNIFE PASSED THROUGH FIVE CORPORA.



FIGS. 5 AND 6. FROM SECTIONS OF OPOSSUM OVARIES, GREATLY MAGNIFIED

FIG. 5. MARGIN OF A GRAAFIAN FOLLICLE, SHOWING RIPE EGG WITH POLAR BODY AT LOWER RIGHT AND CHROMOSOMES WITHIN THE EGG. FIG. 6. MARGIN OF CORPUS LUTEUM, THE LARGE CELLS OF WHICH ARE THE METAMORPHOSED NURSE CELLS SHOWN IN FIG. 5.

a Graafian follicle by examining a number of stages. The egg at first is structurally the center but always remains the physiological center, for without egg no growing follicle. The egg itself increases during its period of growth ten times in diameter, a thousand or more times in volume, while its nurse cells multiply until many layers deep. By this time the growth of the egg is nearly complete, but this is not yet "mature." A vascular tunic surrounds the whole, for now more nourishment is needed.

The next step is the secretion of the liquor folliculi which begins to accumulate among the cells, pressing them farther and farther apart in large fluid-filled spaces which coalesce into a great space or antrum (Fig. 3). Finally the follicle is like a clear, bladder-like cyst that bulges from the ovary by virtue of its shape and size. The egg occupies a little hillock of nurse cells somewhere—anywhere—on the follicle wall. All this secretion probably goes on under the direct stimulus of the anterior lobe (Fig. 1).

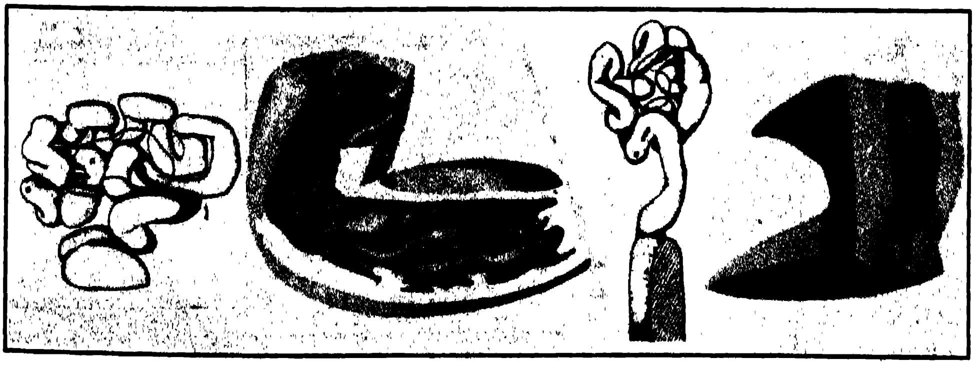
Now what has all this secretion to do with the egg? The function of the liquor folliculi is twofold: it affords a medium for carrying out the egg at flood tide, as it were, when the follicle bursts; and second, it constitutes an internal secretion which is absorbed by the mother for the further preparation of her body for the care of the egg.

The hormone of the follicle has several functions, partly identified by names applied to it: (1) *Folliculin,* because formed by a Graafian follicle. We now know, however, that it can be secreted by x-rayed ovaries devoid of follicles, and it is found in the placenta in large amounts, and may possibly even be made there. (2) *Oestrin* is a more expressive term, for the test of its presence is oestrus or "heat" produced in spayed mice or rats. (3) We might finally call it the *female sex hormone,* responsible, among other things,. for the secondary sex characters of the female. (4) It now appears that an important function of this outpouring of liquor folliculi is the *stimulation of the anterior lobe*, in preparation for the next step, the formation of corpora lutea, as we shall see presently.

Let us return to the large follicle of the monkey ovary. Among the many unanswered questions that arise at every step of our story is this: Of the thousands of primordial follicles that lie dormant in the monkey ovary, why should a certain one be singled out and suddenly begin to grow and swell like a mushroom? This phenomenon speaks for a beautifully controlled mechanism. The anterior lobe is the prime mover in this process, but so far attempts to imitate nature with transplants of the gland or extracts have resulted only in a wild growth of many follicles. What the controller is that normally puts on the brakes at the proper time and place we do not yet know. It has been suggested that the inhibitor is the follicular hormone of the one follicle that gets the head start, as indicated by the arrow in Fig. 1.

In our story we have now arrived at the point where the mature egg in the mature follicle is ready to be liberated. Such an egg has one half the chromosomes of the species (24 in the rhesus monkey as in man). One half of the chromosomes have been discarded and are to be found in the polar body. Fig. 5 shows such a polar body and some of the chromosomes of the ovum. Such an egg is ready, as soon as discharged, to meet the sperm or male sex cell in the process of fertilization, as will be fully elucidated in the succeeding lecture of this series. Fusion of the gametes, female and male nuclei, takes place in the upper reaches of the oviduct in the monkey, as probably in all mammals including man.

In the bursting of the follicle to liberate the egg we are confronted by the enigma of its physiological causation. Most mammals, including man and monkey, ovulate spontaneously, that is, in the absence of the male. The rabbit, the ferret and the cat are different; in these mating is necessary for ovulation. In the rabbit, almost precisely ten hours after mating the eggs are discharged from the ovary. If we couple this fact with the finding that the female rabbit can be made to ovulate by the injection of anterior lobe hormone, we may suppose that normally nervous excitation stimulates this gland, so close to the



FIGS. 7 AND 8. SKETCHES FROM ENLARGED WAX MODELS OF THE OVIDUCT OF THE RAT (FROM HUBER)

IN 7A AND 8A. THE TRANSIENT EGGS ARE INDICATED BY TINY RINGS; IN 8A FOUR EGGS HAVE NEARLY REACHED THE UTERUS. FIGS. 7B AND 8B. DETAILS OF THE PORTIONS OF THE TUBES CONTAINING THE EGGS.

brain, to put out an "ovulatory" hormone.

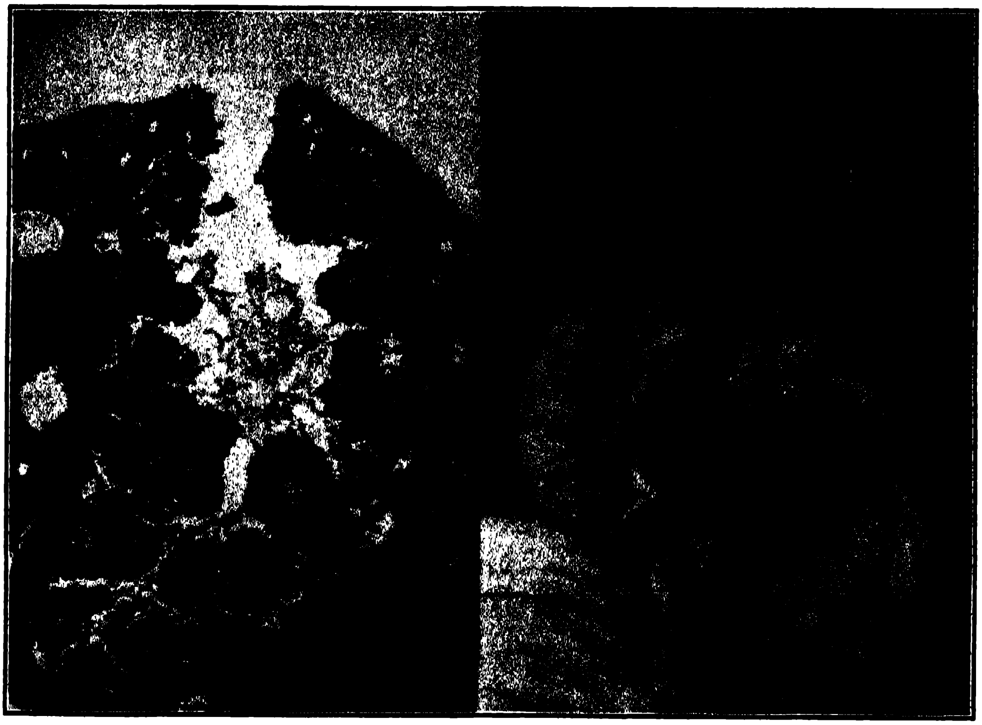
Ovulation, then, is a most momentous act, the *sine qua non* of reproduction. It marks the culmination of long preparatory processes. A four-year-old monkey, just mature when ovulating for the first time, has been engaged for four and one half years in preparation for the act, for we must include the prenatal as well as the postnatal development.

The wandering of the egg (Figs. 7 and 8) now fertilized, to its "nesting" place or implantation site offers interesting and unsolved problems. The egg, discharged upon the ovarian surface and literally deposited into the body cavity, finds its way into the tiny lumen of the oviduct through the mediumship of the fimbriated opening or "funnel" leading into it. This consists of folds like far-flung neck ruffles—soft expansible flaps that are highly mobile, especially at ovulation time (Fig. 10). The funnel edges envelop the ovary-like broad bands and are, moreover, covered with cilia that waft a stream of peritoneal fluid into the tube which thus carries the egg with it. The motility of the funnel and even the very presence of cilia depend upon ovarian hormones elaborated concomitantly with the development of the egg and exerting their influence just at the right time. Whether ciliary action is entirely responsible or is even important in the transfer of the egg down the tube to the uterus is not yet settled. The alternative theory that the contractions of the muscular wall of the tube are largely or entirely responsible seems very reasonable. The passage of a bolus of food down the intestine offers a parallel. It is certain that just about ovulation time the tube is very active but the spontaneous motility gradually subsides. More remarkable than the mere passage of the egg is the fact that it requires so long as it does, namely, three days, for most mammals, large or small, for example, cow or mouse. In other words, the passage into the uterus is delayed, doubtless to give that organ time to prepare for its reception. This slow passage is probably associated with the sluggishness of the tube which is brought about by the successor of the ruptured ovarian follicle, the corpus luteum.

A problem analogous to the transport of the fertilized egg *down* the oviduct is the transport of the independently motile male sex cells, the spermatozoa, *up* the genital tract. Is it by its own efforts, by the lashing of its vibratile tails, that the spermatozoon reaches its mate? Is it by a stream of upward-beating cilia as in birds and reptiles? Or is it by the never-ceasing muscular contraction of the maternal organs, that the fathering elements are carried passively and resistlessly along? Facts are accumulating to show that the last theory is the most likely one, a conclusion which would explain the high degree of motility of uterus and oviduct during the "heat" period when the supply of folliculin is at its height.

In the last few paragraphs the reader has been reminded of further purposive events transpiring in the prospective mother's body—changes in the endocrines, responses by the mother's organs, calculated to nurture and transport the precious egg—not too fast, not too slowly, so that events may synchronize and processes harmonize. How much influence the free egg itself exerts is problematical, but probably none so early in its history.

Let us leave the egg, three days older but not a whit larger, resting for a time in the lower end of the oviduct ready at the next signal to enter the more cavernous uterus, and let us return to the collapsed follicle that has given up the egg it had nurtured to maturity. It is like a building after an earthquake.

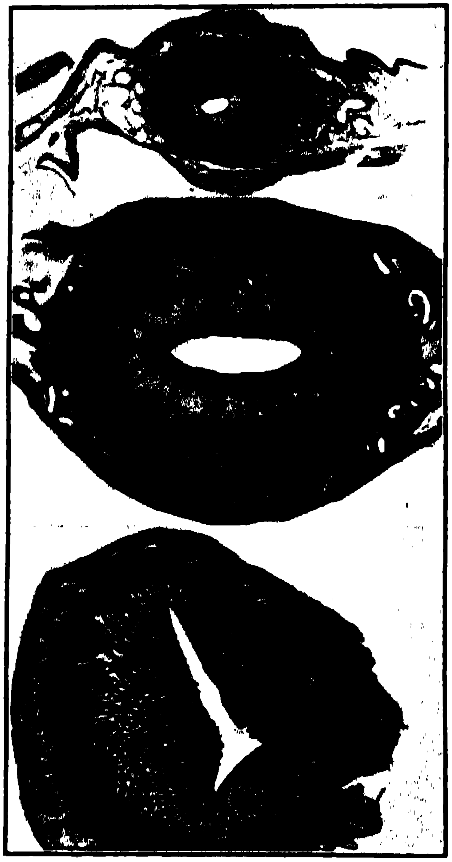


FIGS. 9 AND 10. SECTION OF COLLAPSED, FRESHLY RUPTURED FOLLICLE, SHOWING POINT OF RUPTURE THROUGH WHICH THE EGG HAS ESCAPED. FIG. 10. DISSECTED OVIDUCT OF THE OPOSSUM, SHOWING LOOSE FIMBRIAE THAT EMBRACE THE OVARY TO CATCH THE EGG; PHOTOGRAPHED FRESH IN WATER.

All is chaos at first—blood, nurse-cells, capillaries and connective tissue all topsy-turvy (Fig. 9). But from the wreckage, phenix-like, arises a new structure. The nurse-cells metamorphose in a marvelous fashion. Some of them may multiply, but all of them swell to twenty or more times their original volume. Eventually their aggregate volume stops the gap and more, for the new gland, now an almost solid structure, may exceed the mature follicle in volume (Fig. 4). The nurse-cells soon contain fine fat granules and "lutein," which imparts a yellow color to the structure and has given rise to the name corpus luteum or yellow body. This luteinizing change is probably under the control of the anterior lobe, whipped into this new action by the liquor folliculi spilt at ovulation and resorbed by the blood. The corpus luteum is a typical gland of internal secretion. Blood vessels have grown in among the cells so that there are none but what lie contiguous to capillaries. Here the blood takes up from the cells and carries to the uterus the chemical messengers needed for the further development of the egg. The very structure suggests a gland (Fig. 6). That it is a gland is conceded, but its functions have been the center of controversy for thirty years and the end is not yet. If we will summarize some of the alleged functions of the corpus luteum we shall at the same time learn something of the needs of the developing egg.

(1) Before the advent of the egg in the uterus and its attachment there, the

corpus luteum prepares the lining of the uterus to make it a fit nesting place. The membrane becomes swollen, fluffy, well supplied with blood, secreting "uterine milk," so called, for the nutrition of the egg. Figs. 11 to 13 show stages in the growth of the monkey uterus, the last marking the condition of early attachment. Corpus luteum extract injected into rabbits or monkeys will bring this necessary "pregravid" condition about, probably directly, although here again the anterior lobe may play a part, acting under the stimulus of the corpus luteum as it previously acted under the stimulus of the follicular hormone (Fig. 17).



FIGS. 11 TO 13. SECTIONS THROUGH THE ADULT MONKEY UTERUS

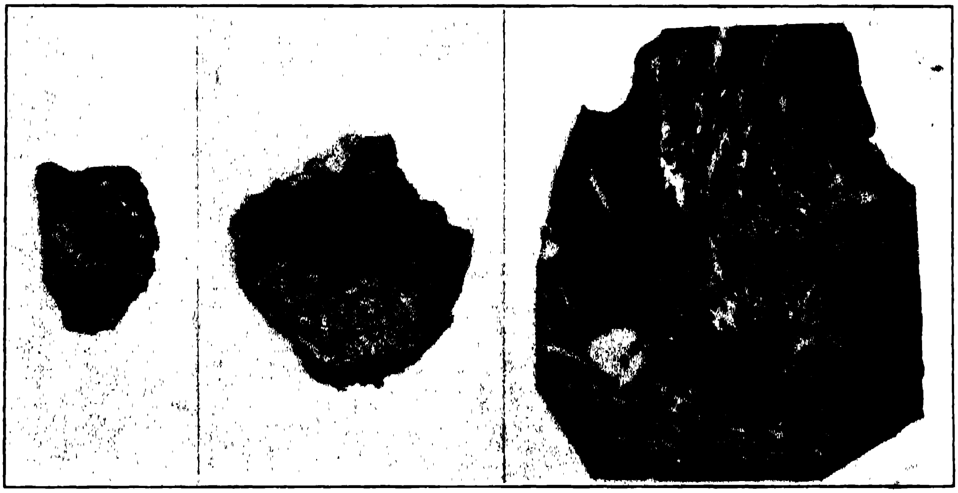
FIG. 11. THE "RESTING" STAGE, NOT YET WHIPPED INTO ACTION BY THE ENDOCRINES. FIG. 12. THE PREMENSTRUAL ORGAN ACTED UPON FOR SOME DAYS BY THE CORPUS LUTEUM. FIG. 13. UTERUS WITH A 19-DAY OLD EGG IMPLANTED (DARK SPOT). THE GLANDS HAVE DEVELOPED CONSIDERABLY UNDER THE 19-DAY INFLUENCE OF THE CORPUS LUTEUM.

(2) The pregravid preparation just referred to takes place in the monkey and in women during each monthly cycle; but if the egg is present and attaches itself certain connective tissue cells about the egg swell until they look like typical gland cells. Decidual cells they are then called, that form the decidua, whose function we shall note presently. Now, the corpus luteum has been found to sensitize the connective tissue cells of the uterus, so that, on irritation, this metamorphosis of small slender cells into large rounded ones takes place. But the anterior lobe extract will do the same; perhaps the corpus luteum actually performs the function via the anterior lobe—another doubt that faces us in these complex relations.

(3) Since it is obviously needless during pregnancy for more eggs to mature or more follicles to grow, this function is for the time suppressed. Until recently the corpus luteum was supposed to perform this function of suppression. But other factors, little understood, are known to be effective in this direction, for instance, lactation.

(4) Once begun, the pregnancy is continued under the ægis of the corpus luteum, at least in the early stages, for castration leads to the death of the embryo. The guardian angel, the corpus luteum, may not act on the embryo directly, but probably serves this guest by providing an active blood stream to be maintained through the organ.

(5) The corpus luteum has been supposed to prepare the mother for birth, by relaxing the birth canal, loosing the ligaments of the pelvic bones, modifying liver, kidney and other organs. But it is more probable that it is the ante-



FIGS. 14 TO 16. MAMMARY GLANDS OF THE MONKEY, trimmed from the skin and spread. Fig. 14. The dark area in the middle is the poorly developed mammary tree of an immature female. Fig. 15. Adult, "resting" stage. Fig. 16. Late in pregnancy.

rior lobe that does this, acting under the stimulus of the egg, embryo or fetus, which brings about these profound changes.

(6) When the baby is born the breasts must be ready to nourish it. The preparation for lactation requires the entire period of pregnancy and consists in growth of the "mammary tree," the secretory alveoli and the milk ducts. Figs. 14 to 16, monkey breasts removed from the skin, illustrate the point. This growth has been attributed to the corpus luteum but has now been shown also to be an anterior lobe effect. The experimental results are in keeping with the observation that the mothers whose ovaries are removed during pregnancy may still suckle their young.

We thus see that from somewhere emanate hormones that transform the pregnant mother in a most marvelous fashion (Fig. 17); but these hormones are elaborated only under the whip of the egg that constantly sends out orders, as it were, that its needs may be met. The mother responds to the limit of her vitality. If she has weak organs, the added demands of gestation will find them out. The corpus luteum had at one time the chief honor of "train dispatcher," but the anterior lobe is now thought to dominate the reproduc-

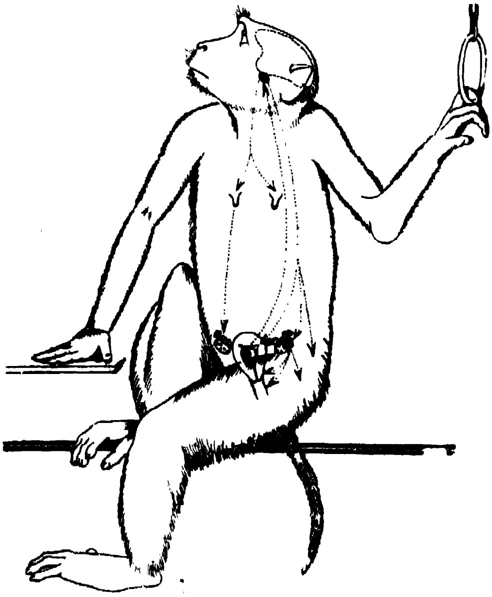


Fig. 17. Outline showing the interplay of some of the endocrines in pregnancy.

tive functions of the body through its chemical messengers sent by the blood stream to the various organs.

Let us now return to the egg. For several days it floats free in the uterine cavity. About the eighth or ninth day in the monkey it becomes sticky and attaches somewhere near the upper end of the uterus. It immediately begins to dig in—it becomes a true parasite upon the mother. The maternal tissues melt away before the erosive action of the tiny egg, which must tap the mother's blood supply. In the monkey it becomes half buried (Fig. 13), in the human species entirely so. It would go deeper but for the fact that the decidua, just referred to, walls it off (Fig. 18) to prevent its over-riding the bonds of safety on the part of the villi, those feeding tentacles or suckers that sink into the maternal tissues. The villi contain embryonic blood vessels and dip into the maternal lymph spaces, absorbing the life-giving material. Pieces of villi may break off and enter the maternal blood stream, setting up reactions, partly beneficial, but in excess, detrimental.

As the embryo and its placenta grow they make greater and greater demands, sending out chemical messengers that call out tremendous responses on the part of the mother. The muscle cells of the uterus increase fifteen fold in size, the connective tissue becomes stronger, more succulent, expansible, rejuvenated. Cervix and vagina are prepared for a birth canal by similar changes. Means are suited to ends in a most marvelous fashion. Only a beginning has been made by anatomy and physiology in the elucidation of cause and effect in the processes by which a baby is nurtured and born.

The culminating enigma is the cause of birth. At the physiological moment, as yet predictable only within wide limits, the fetus becomes a foreign body to be expelled. For twelve days in the opossum (Fig. 19), a month in the rabbit, six lunar months in the monkey (Fig. 20) and ten in man, two years in

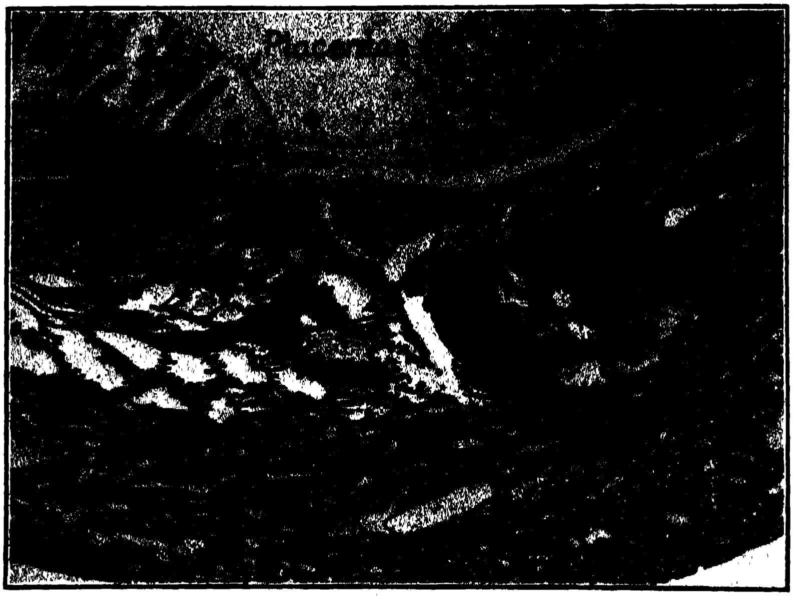
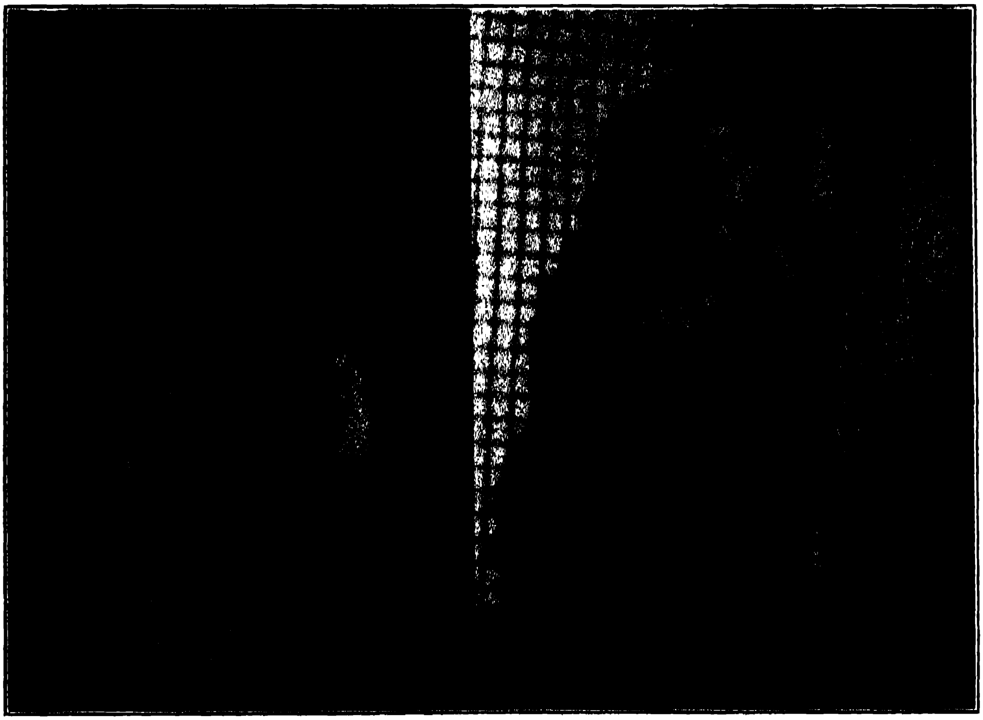


FIG. 18. A PORTION OF THE UTERUS WALL AND PLACENTA OF MONKEY ON THE 29TH DAY OF GESTATION, SHOWING DECIDUAL BUFFER.



FIGS. 19 AND 20. TWO EXTREMES IN THE SPAN OF GESTATION

FIG. 19. TWO OPOSSUM POUCH YOUNG ABOUT A WEEK OLD, NATURAL SIZE. THE OPOSSUM IS BORN 12½ DAYS AFTER CONCEPTION. FIG. 20. NEWBORN BABY MONKEY, STILL WET; GESTATION SIX LUNAR MONTHS.

the elephant—for a limited time the fetus is a welcome guest, like an organ of the mother's body. Without any warning, so far as we now know, the zero hour arrives, after which pain gives way to the joy of motherhood. We are experts in reading the calendar, but on the *why* of the onset of labor Aristotle was as wise as we are to-day. It should be added, however, that important results are promised in this field from a study of uterine motility in relation to the endocrines.

More is known about the cyclic monthly changes in the absence of pregnancy. Each cycle is an abortive pregnancy which recapitulates gestation in miniature. The cause of the periodicity is doubtless a complex interaction of the glands mentioned in connection with the care of the egg and its nutrition and expulsion, the ovary and the anterior lobe occupying the center of the stage. Thus under the influence of the anterior lobe a follicle grows; it ruptures, liberating follicular fluid; this is resorbed and fires the anterior lobe to new action, and the follicle becomes the corpus luteum; this dies and a cycle is started anew. The egg rapidly dies, too, unless fertilized, perhaps in only a few hours. If so it exerts no influence and another moon must pass before another dies—or lives to join the immortal stream of protoplasm that began when life began and will continue till life ceases.

—*Photograph by Professor McAdie*

FOG CHANGING TO CUMULUS CLOUD.

ONE HALF HOUR MADE A DIFFERENCE BETWEEN A DENSELY FOGGY MORNING AND BRIGHT SUNSHINE.

THE CONTROL OF FOG

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If you ask some prominent astronomer concerning the nature of the stars, he will quote inconceivably high figures for stellar surface temperatures, also equally appalling data for densities at the centers of stars. Ask another distinguished astronomer and he will correct the earlier figures, explaining that his colleague doubtless worked from the surface of the star inward, whereas in his judgment the proper procedure is to begin with values at the center and integrate outward to the surface. Consult now some authority on physics familiar with the basic equations, and he will point out that even the minimum values given are inconsistent with established thermodynamic laws. In short our authorities on stellar structure today are at variance; and in Europe are somewhat emphatic in protesting views other than their own. American astronomers say less and seek further observational data. One of the most prominent says "he knows that he doesn't know"; which gives most of us who are in the rear guard great satisfaction.

But while there may be confusion in estimates of star structure and conditions, all astronomers and astrophysicists agree that the stars are stupendous gas houses, burning furiously. Any object drifting within millions of miles of one of these vast storehouses of blazing gas would be shrivelled and scorched instantly, so great is the heat. Our familiar friends of night, so constant and so dependable, are in reality only gigantic flames. Like so many lighted candles they must in time burn themselves out, leaving nothing. Our universe and presumably the farthest galaxies are blazing furiously; and heat is being diffused in space at a rate beyond human conception.

All creation is afire; *all but the earth*, for the serio-comic aspect of the situation is that amid all this lavish waste of heat, the little speck of matter on which we live is slowly freezing to death. Unlike the stars it is non-gaseous and incapable of producing its own supply of heat, even enough for home consumption. Man and all his works are doomed to be entombed in a wall of ice. Civilization will end in a never-to-be-broken sleep, under a great sheet of solid frozen water. Somewhere the last man (let us hope in an attitude of protecting the last woman) will throw up his hands and be overwhelmed in the ice flood. Nothing that human agency can devise will melt or stay the encroaching, all-embracing universal glacier. The astronomical forecast presages a cold fate, a chilled faith and a congealed hereafter; and Dante's uttermost hell will be right here on earth and not beneath as the poet imagined.

The five interglacial intervals that the earth has already experienced in the Pleistocene Ice Age are but the advancing and retreating waves of a slowly rising tide, ultimately submerging all. Notwithstanding this cheerless prediction of ultimate frigidity, we can afford to be cheerful, for astronomers are often confounded, and remarkable and unexpected discontinuities do occur in the behavior of celestial bodies. More pertinent still is the fact that the earth loses its heat at so slow a rate that millions of years must elapse before the freezing point is reached. Perhaps the second law of thermodynamics, the law

—*Photograph by Professor McAdie*

FOG CASCADES.

LOW SEA FOG AS DISTINGUISHED FROM GROUND RADIATION FOG. THE AVIATOR MUST PICK AND CHOOSE IN LANDING.

that insists on the running down and heat death of every thermal engine, may meet with a jolt, and actually show reversal. So there is no need of worrying about our ultimate fate.

If now we venture to make the novel assertion, not yet advanced by any geophysicist, that a fog bank is in its way the forerunner of an ice cap, we shall not be far astray. For the essential difference between ice, water and vapor, invisible or visible, is simply a matter of molecular freedom; that is, the excursions of the molecules of this mixture of hydrogen and oxygen may be described as fixed, fluid and free. Picture a hundred school children in a crowded classroom, quiet and making no noticeable commotion. That is the solid condition found in ice. Now let there be a recess and these hundred youngsters, who for our purpose are molecules, go storming out to play. They jostle each other and run about freely, even as in the liquid water the molecules slide on one another and have a certain freedom of motion. Finally imagine each child to be provided with a moth airplane painted a dirty gray. Now they jump away from the ground and move hither and yon in the air. This corresponds to the vapor state. Let our flying children hug the earth and crowd one another, and we have a condition comparable with condensation of water vapor into cloud or fog. A cloud is nothing but a fog that by virtue of a slight excess of heat has developed a lifting force and so rides high. Conversely a fog is a cloud that is earth bound.

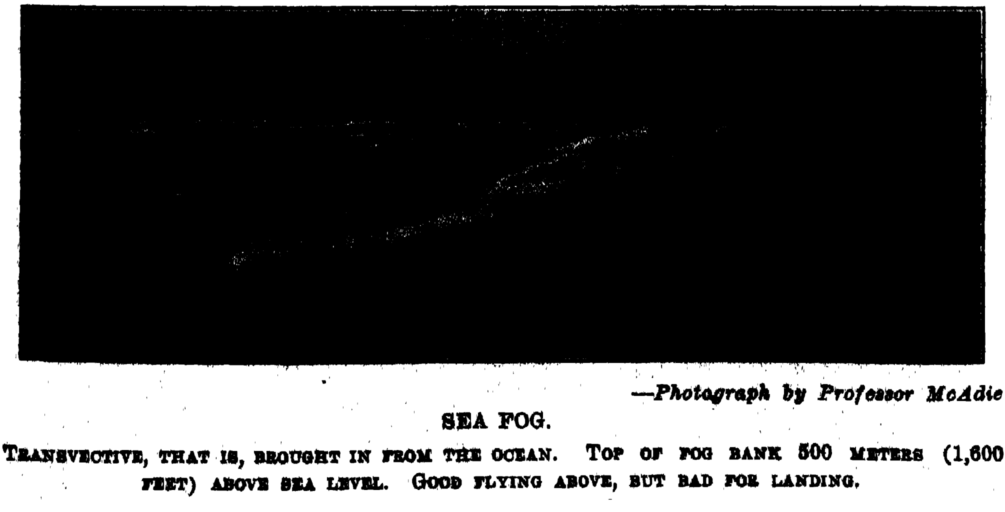
The great glaciers that once swept southward, grinding and crushing everything in their way, were originally compacted and compressed snow fields; and snow crystals are only water vapor molecules that lost heat so suddenly there was no time for assuming the form of a cloud globule or fog droplet. It is as if our school children painted their planes a beautifully pure white, arranging also to have the wings project like six pointed stars. Let these snowflakes fall gently to earth in innumerable numbers, and accumulating year after year, in Arctic regions, form great rivers of slow-moving ice. Large chunks break off and float away as icebergs moving south.

Few transatlantic passengers, sighting at a distance the glistening crest of a berg, realize that the ice was once warm water vapor in mid-latitude if not equatorial seas. The molecules springing free because of their heat energy were borne aloft by an uprising air current. As the air expanded and pressure decreased, there was consequent chilling. Crowding together, the vapor particles became a snow cloud. Carried northward on some thermal air thrust, ever cooling, with its store of heat, like life-giving energy, almost exhausted, the flakes fall finally on the far-stretched ice fields of polar regions.

Not inaptly then may we regard fog in a new light, as the forerunner of the ice; the water form that happily did not carry on, that died, so to speak, halfway on the journey from equator to pole or from some local hot source to a cold sink. But it did not lose its capacity to cover and enfold. Its opacity increases, and, like an embryonic ice wall, it can wrap all things in its embrace.

The danger of an ice tomb is not imminent, and we need not think we shall escape taxes, senatorial insurgency, sumptuary laws and all that give spice and variety to life; but the imminence of fog embracement is only too evident and we do not escape its threats of danger. Such a pall makes us suspend for the time being many of the activities of life, and retards others. We read at frequent intervals of the evil-smelling fogs of Flanders and the Dutch lowlands. The fogs of London are a byword; and it has recently been published that on certain days in December, 1930, the loss to shipping in the port of London was at the rate of £1,000,000 for each day of dense fog. But we need not go so far afield for an instance of large loss due to fog. The month of March, 1929, furnishes a striking example. On the 13th it was unusually warm along the Atlantic seaboard. Without doubt many molecules were skipping about over the ocean's level brim; but no human eye could see them. On Thursday the 14th the wind swung around from the west to the east, and so a steady stream of water vapor came rolling in along the coast from New Jersey northward. Later the wind swung to southwest and a murky warm fog settled down over New York City and its environs. Transatlantic liners inbound and outbound were forced to anchor. On Friday the 15th the murk was even worse. Those clever and exceedingly expert fog dodgers, the ferry pilots, decided it was best to abandon all schedules. Commerce was suspended, only a few harbor craft groped their way with constant tooting of whistles.

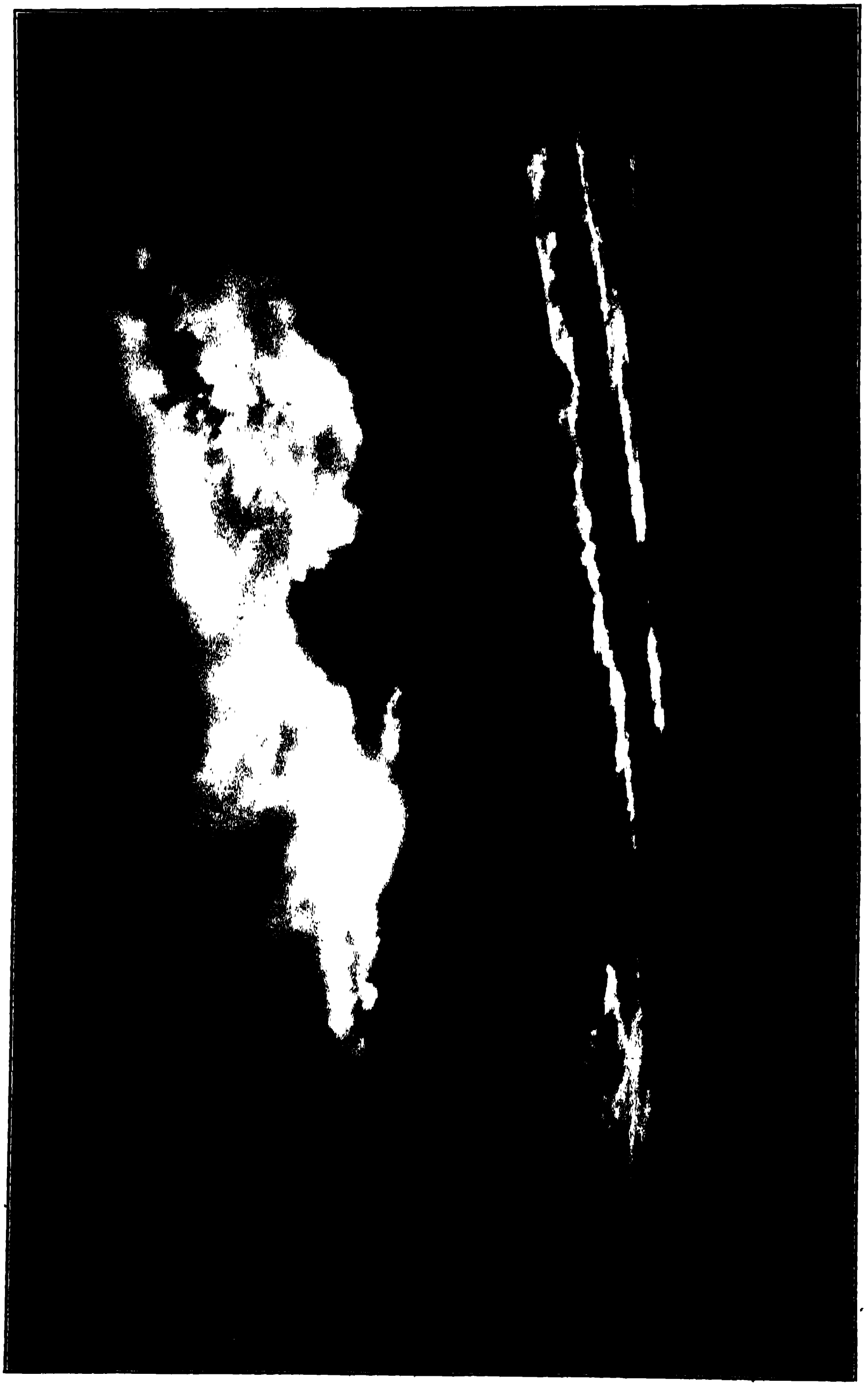
Even on land vehicles moved slowly.



—Photograph by Professor McAdie

SEA FOG.

TRANSVECTIVE, THAT IS, BROUGHT IN FROM THE OCEAN. TOP OF FOG BANK 500 METERS (1,600 FEET) ABOVE SEA LEVEL. GOOD FLYING ABOVE, BUT BAD FOR LANDING.



—*Photograph by Professor McAdie*

LOW STRATO-CUMULUS.
NOT DANGEROUS, BUT WINDY.

It was the densest, most persistent fog known in twenty years. The daily press gave long descriptions of distressing scenes at railway and ferry terminals. Commuters herded in waiting rooms fretted and swore to no avail. Until near noon on Saturday the 16th, the fog was so dense that objects ten yards distant were swallowed up in the murk. This home-brewed *smog* (smoke-fog) was as murky as a London "pertickler." New Yorkers rising from their beds on each of the three mornings found it unnecessary to pull down the window shades. (In the metropolis it is customary to do so, when starting to dress.)

This was a dirty fog, one of the pea-soup brand. On the first day there were over 200,000 dust particles in every cubic meter of space, on the second day 1,600,000. Just before the end there must have been 6,000,000 dust particles per unit of volume. This means that if one scooped up a handful of the all-pervading, there would be in the catch fully 50,000 dust particles; and on each particle a varnish of water vapor. Small wonder that visibility was poor.

Here was a glorious opportunity to demonstrate the efficiency of fog dissipators, whether by adding heat, spraying with electrified water, or by vigorous fanning, and the injection of streams of turbulent air eddies. Nature, however, scattered the fog, in its own large way. The cure was strenuous and speedy, the brushing so energetic that to many the cure was as nerve-wrecking as the complaint. The whole barrier of fog stuff was blown away in an hour. It was of course our old friend Skiron, warder of the northwest wind, on the rampage. He came on the scene, buffeting with lusty blows the mild-mannered Notos and the muffled Euros, guardians of the south and southeast wind. His mighty breath, in gusts that traveled a mile a minute, turned all things topsy-turvy. He respected neither gods nor men, nor even a procession to a saint. For swinging up Fifth Avenue with stately steps and slow, the customary St. Patrick's Day parade had just reached the reviewing stand. Then it was that Skiron turned Sassenach. Like the Assyrian of old he came down on the fold. In a jiffy he knocked off hats from every head. A thousand silk toppers of assorted vintages went tossing on the breeze. They were borne skyward but not on the wings of song. Coat tails, hitherto sedate enough, designed to cover substantial parts of the human anatomy, became possessed of seven devils. With hilarious impudence they flapped in places where they were not wanted. Badges were torn from the imposing fronts of the city fathers; and stern-faced color guards, strong to face the wind, realized that whichever way they turned they had better have turned some other way. Nor did the ruffian, Skiron, spare the skirts of sisters and sweethearts. Graceful draperies sprang into life as parachutes, revealing much not usually disclosed to the eye of man. But the fog was conquered. Farther north, as in Boston, the turbulence developed into a thunderstorm; illustrating perhaps even more directly the instability of air masses in which large quantities of warm water vapor are underrun by strong cold air streams.

These commotions are found quite frequently in the clouds, at moderate heights above ground. We sometimes call these malevolent outbursts squalls, and they constitute one if not the leading menace to safety in flying. Fogs, squalls, lightning and ice coats must all be reckoned with; and in each and every case we find water vapor as the initial disturber of the peace. It is the vapor molecule that starts the row. Cold air underrunning warm air may produce invisible air whirlpools; but when the warm air is heavily laden with water vapor, and the molecules of the latter are ordered as it were to quit instantly their free excursions and get back at once into the liquid or solid state, then trouble begins, with a black-browed cloud, or if close to ground a dirty fog. Eddy currents, technically called *anakatabats* (up and down rushes), make a veritable aerial whirlpool. It was in such a commotion that the good ship *Shenandoah,* daughter of the stars, was caught and flung now down, now up, until the control cars and the main ship were wrenched apart. So, too, with the *R 101,* while the chief cause may have been leaking gas containers, there is no doubt that down rushes in the fog caused such severe bumping that fire started and the catastrophe followed. Nor are planes exempt. The best of pilots may find himself unable to dodge evil-looking clouds, for what seems lightest may become darkest in a moment.

Ice will form from sub-cooled water and adhere to the propeller as well as to the wings, ultimately forcing the plane down. Caught in a down rush the plane may drop a thousand feet in a minute, only to shoot up again with equal velocity. In nearly all the long distance flights from Great Britain to India and Australia, there are vivid descriptions of struggles with squalls. And every balloonist who has survived being caught in a thunderstorm can tell a graphic tale of the way in which these currents tossed the balloon about.

But the fogs of the Great Banks are not this way, some one will say! True, they are not; and there are many kinds of fogs. It is a rather quiet but persistent pall of fog that overlies the Grand Banks. Faith, we are told, is the substance of things hoped for, the evidence of things unseen; and it requires faith, when crossing the Atlantic and plugging on during the third and fourth days through an unending cover of fog, to believe that the sun is still high in the heavens. Soundings have been made, however, in this fog, and we know that the layer is not very thick, in fact, some of the tall buildings in New York, if it were possible to remove and erect them above the Grand Banks, would have the upper floors flooded with sunlight. Looking down on the far-flung sea of ruffled fog, with sun-tipped billowy crests, the occupants of the upper floors would chant in chorus:

> "If seven maids with seven mops
>   Swept it for half a year!
> Do you suppose," the Walrus said,
>   "That they could get it clear?"
> "I doubt it," said the Carpenter,
>   And shed a bitter tear.

We share the Carpenter's doubts. Some kinds of fog can be dissipated, as will be shown later; but in the case of the Grand Banks, the supply is so large that the contract is beyond our undertaking.

It has been seriously proposed to spread a film of oil over the ocean, and thus prevent evaporation, strapping the molecules down tightly to the water, as it were. Then, no matter how much heat was abstracted, there could be no vapor to condense and hence no fog. But there would still remain the necessity of damming two great rivers of air, one bound northward heavily laden with free and far-skipping molecules, and the other blowing from cold, bleak Labrador, crowding the warm current. Sir Napier Shaw told us some years ago in his "The Air and its Ways" that the bulk of the water in an Atlantic fog (and it takes only a thimbleful of water to make a hogshead of fog) came from the south and not as hitherto accepted, from the water in the vicinity. Therefore, as we can not fence off Skiron from Notos, the sweet-tempered bearer of the water jug, we can not prevent the pushing and jostling marked by the formation of fog. Far to the east, Notos pursues the even tenor of his way, and gives warmth to the British Isles—a warmth quite generally but erroneously attributed to the Gulf Stream.

Whenever cold and warm streams meet, be they of water or air carrying water in the invisible form, there will fog form; and the density be proportional to the temperatures involved. Officers of the Ice Patrol say that it is easy to recognize the boundary between polar water and the Gulf Stream. Off the tail of the Grand Banks these currents abut with such remarkable distinctness that the wall—the Cold Wall—can sometimes be detected, extending down to a depth of 200 fathoms. The juxtaposition of currents with marked temperature contrasts results in startling atmospheric anomalies. A steamship may at times run into fog so dense that the captain on the bridge can not see the bow; and conversely we have well-authenticated cases of ships emerging from a wall of fog with the forecastle in clear air and the stern in fog. It would seem to be beyond our power at present to dissipate fog of such density.

Likewise, we can hardly hope for success in scattering the fog of the West Coast, the tide that, for example, pours through the Golden Gate every summer afternoon. This is due to upwelling cold coastal water overlain by warm moist air. An actual attempt to clear away the fog at San Francisco by discharging electricity of high voltage was not successful, but it must be remembered that here again, as off the coast of Newfoundland, the vast supply tends to mask any perceptible diminution by artificial agencies. Nature does, however, dissipate the Golden Gate fog every day in an exquisite way. One has only to climb the Berkeley Hills and look down on the fast-fading fog. The valleys supply the requisite heat, the fog droplets change into fast-flying molecules, escaping from their thraldom, and nothing remains but the velvet touch of the summer breeze.

Of the various methods of dissipating fog that we have seen and tried, that of spraying with electrified water jets seems to be the most effective. Electrified sand and air are slower. Electrified smoke has not yet been tried to any great degree. In the laboratory we have no difficulty in clearing away smoke by passing a spark of some length across the container. Two or three seconds will suffice to clarify a dusty, smoky atmosphere. Out in the open, however, we have not met with the anticipated success. We have examined microscopically the dust content of air before and after the passage of near lightning, also real lightning. The former experiments, tried and repeated through the courtesy of the General Electric Company at their high tension experimental laboratory, involved a flash four or five meters in length with a voltage of over two million. Likewise with real lightning we have not found the clearance to be as marked as anticipated. The clarification of the air, following a thunderstorm, which every one can notice, is due more to mechanical replacement of air than to the tremendous throwing effect and repulsion accompanying high potential discharges. But further experimentation is necessary, where conditions are more under control of the experimenter.

We believe, however, that it is quite practicable to dissipate the shallow ground radiation fogs of morning, following a still clear night with characteristic temperature inversion. Indeed, some of these fogs, as on August mornings over the water approaches to New York (and of course at other important commercial points), could be dissipated without great expense, utilizing, for example, the powerful streams of the fire boats. Electrified spray from these mighty nozzles would not only wash a channel in the fog, but cause the fog droplets to coalesce and agglomerate and drop as a drizzling rain.

The subject is not to be dismissed without a short reference to the good side of fog embracement. In naval maneuvers and mimic warfare, the planes throw out a smoke screen, and this can rest on the surface of the water or hang high in air to hide the bombers. The use of a fog screen as a defense can be traced back to mythological times. Does not Homer picture the infuriated Achilles about to hurl a rock so big that two men could hardly lift it, at the head of Aeneas, who had foolishly hurled his spear at the mighty leader of the myrmidons? Then it was that a certain goddess wrapped the future hero of Vergillian verse in a fog; and the son of Peleus knew not where to throw the rock. So, too, with Nelson and Napoleon. The latter, fleeing to Paris from Egypt, fearful of consequences at the hands of an angry Directorate, slipped by the watchful admiral in the fog. The Little Corporal got by, else Austerlitz and Waterloo had not been spread on history's pages.

And there was one day in the World War when fog overpowered both sides. A full moon lit up the battle front from Loos to Fresnoy on the night of May 6, 1917. Next night it rained, but the guns never ceased firing. It was the supreme artillery effort of the war, and along a fifty-mile front every available gun was in action. Then came dawn, with the light dimmed by gathering mists. As the minutes passed, the fog thickened. Without sound or murmur a wall of white swallowed the contending armies. Mute but masterful, the fog countermanded all battle orders. The roar of a thousand batteries gave way to stillness. And we venture to think that on both sides a suggestion to employ fog dissipators would not have been received with enthusiasm!

THE HEREDITY OF THE BLOOD GROUPS

By W. V. LAMBERT

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THE study of heredity in man presents one major difficulty not encountered in other species. The direct genetic approach being impossible, students of human heredity have to rely upon mass statistics, and upon the often fragmentary record of family pedigrees as the source of data for their conclusions. It seems remarkable, therefore, that the heredity of obscure biochemical properties of the blood should be among the best known of all inherited human traits.

For the discovery of these properties, the human blood groups, the world is indebted to Dr. Karl Landsteiner, a discovery for which he was awarded the Nobel prize in medicine in 1930. This award has, naturally, focused the attention of many people upon a subject that for years has been of fascinating interest to the biologist, and one which is still claiming the attention of hundreds of workers in biology and medicine. But what are the blood groups, and what further significance have they in biology and medicine to justify their continued study by such a large group of investigators?

The blood groups occur in man as constant, inherited, biochemical entities existing in the blood. The work of Landsteiner and his students was to show that the blood of all people could be placed in one of four distinct groups. For the recognition and study of the blood groups one of the most generally used of the immunological processes, namely that of agglutination, is employed. Since the recognition and study of the blood groups hinges upon the mechanism of the agglutination reaction, an understanding of their nature and inheritance must be based upon some knowledge of the mechanism of agglutination.

THE PHENOMENON OF AGGLUTINATION

If killed typhoid bacteria are injected into the blood stream of a normal rabbit at three- to five-day intervals for several weeks, this animal will form reacting substances in its blood stream against this foreign bacterial protein. These substances are known technically as "antibodies." If, after a period of about two weeks following the last injection, blood is drawn from the animal and the serum has been obtained, the phenomenon of agglutination can easily be demonstrated. The demonstration consists in adding to a suspension of typhoid bacteria contained in physiological saline solution, a small quantity of the serum. If the test-tube containing the bacterial suspension plus this serum is placed in an incubator and kept at body temperature for a few hours it will be found upon reexamination that the bacteria have flocculated or "agglutinated" and settled to the bottom of the tube, whereas the control tube, to which no serum was added, has undergone no change; that is, the bacteria will still be in suspension in the saline solution of the control tube.

The same phenomenon may be demonstrated microscopically. If some of the bacterial suspension plus the serum is placed on a slide and examined under the high power of the microscope the bacteria will be found, after a few minutes, to be aggregating into clumps. No such clumping is to be found, however, if one examines in this way some of the control suspension, the one to which no anti-typhoid serum was added.

This reaction is a highly specific one, the serum of the animal containing antibodies in any appreciable degree only for typhoid bacteria. This high specificity is dependent upon the nature of the protein peculiar to that one species of bacteria, and this specificity is so great that the agglutination test is one of the best of the routine laboratory tests for diagnosing certain diseases.

The bacterial or cellular suspension used for such agglutination tests is known technically as the "antigen," and the flocculating or agglutinating substance present in the serum as the "agglutinin."

Usually, the blood does not contain agglutinins unless their production has been stimulated by the presence of foreign protein in the tissues of the animal, either by injection or through the invasion of the tissues by bacteria, as in the case of disease-producing microorganisms. Likewise, an animal will not develop antibodies against its own tissues and ordinarily not against those of other animals of the same species.

However, there exist in the blood serum of man normal or natural agglutinins which will cause the clumping of the blood cells of other people. These natural agglutinins in the blood serum of man are known as "iso-agglutinins," while the blood cells which show this capacity for agglutination are known technically as the "agglutinogens"; thus corresponding to the "antigen" for the bacterial cells previously mentioned.

The interrelations of the four blood groups with each other will be made clear by reference to Table I. It is apparent from this table that the serum of no blood group agglutinates its own cells, and, further, the serum of group AB does not agglutinate the cells of any other group. The cells of no group are agglutinated by the serum of the blood in which they are continually bathed; while the cells of group O are not agglutinated by the serum of any group.

In cases of blood transfusion a healthy individual of the same group as the recipient is chosen for supplying the blood. This is necessary, for if the cells of the donor are agglutinated by the serum of the recipient of the blood, agglutination will occur within the blood stream, with the subsequent danger of the formation of clots in the circulatory system. Since, however, the cells of group O are not agglutinated by the serum of any other group, it is possible to transfuse the blood of an individual of group O to an individual of any other group. Individuals of group O are, therefore, known as universal donors. Since the serum of group AB does not agglutinate the cells of any other group, individuals belonging to this group are known as universal recipients. Agglutination following transfusion is caused by the recipient's

TABLE I

Group*	Serum agglutinates blood cells of groups	Blood cells agglutinated by serum of groups	In transfusion	
			Can give to groups	Can receive from groups
O	A, B, AB	No group	O, A, B, AB	O
A	B, AB	O, B	A, AB	O, A
B	A, AB	O, A	B, AB	O, B
AB	No group	O, A, B	AB	O, A, B, AB

* Groups O, A, B, AB correspond, respectively, to Jansky's groups I, II, III, IV.

serum and not by the donor's serum, as the donor's serum is too much diluted in the recipient's blood stream to cause agglutination. In actual practice an individual is chosen as donor that belongs to the same blood group as the recipient, rather than a person belonging to group O. This eliminates any possible danger from agglutination of the recipient's cells by the donor's serum, and from other possible differences that may exist between the two groups.

In medicine and surgery this information has been of great practical significance, for it put the operation of blood transfusion on a scientific basis, and thus immediately eliminated most of the untoward results that frequently followed this operation. To-day blood transfusion is used extensively, whereas previous to the discovery of the blood groups it was rarely used.

The agglutinogens, that is the blood cells which show the capacity for clumping, are constantly present in the blood stream throughout life, but the agglutinins do not develop until some time after birth. No clear explanation of this delayed appearance of the agglutinins has been advanced.

Evidence has been brought forward in the last few years which clearly indicates that additional agglutinating elements are present in the blood of some individuals, while many observations have shown that a considerable variation exists in the strength of the agglutinins in different bloods. However, since there is no indication that these additional agglutinating elements occur independently of the main groups, it is not necessary to make any change in the present system of grouping, but merely to consider the possibility of subgroups within the four main groups.

The Inheritance of the Blood Groups

Landsteiner reported his discovery of the blood groups in 1901, but not until about eight years later was it suggested that the blood groups might be subject to the laws of Mendelian heredity. Ottenberg and Epstein first made this suggestion in 1908, and Von Dungern and Hirszfeld established the fact beyond a doubt in 1910. To-day, the manner of inheritance of the blood groups is perhaps the most clearly known of all the inherited traits in man.

According to the explanation of Hirszfeld and Von Dungern, the inheritance of the blood groups could be explained upon the basis of two pairs of independently inherited Mendelian genes. Studies made during the last five years, however, have tended to disprove their conclusions; and it seems more likely, as a result of recent studies, that the inheritance of the blood groups is dependent upon the existence of three multiple allelomorphs. Evidence for this conclusion will be presented following a discussion of the method of the inheritance of the blood groups.

According to the modern conception of heredity, all inherited characters depend for their expression upon factors or genes which are transmitted from generation to generation in the nucleus of the reproductive cells, male and female alike. Furthermore, these genes are carried on the chromosomes, these being the deep staining bodies found in the nucleus of all cells. The genes may be thought of as minute packets of chemicals located in the chromosomes, each gene always occupying the same position on the chromosome upon which it is carried. In the individual the chromosomes are always associated in pairs, one member of each pair having come from the paternal germ cell or spermatozoön, and the other member from the maternal germ cell or the ovum. In man there are twenty-four such pairs of chromosomes, the two members of each pair resembling each other in size and shape, but differing in their morphology from the other pairs.

The twenty-four pairs of chromosomes may be thought of as twenty-four sets of twins, each set of twins being identical, but differing from every other set.

As the chromosomes are the bearers of the hereditary factors, and they are always present in the individual in pairs, then the hereditary factors, which occupy the same location in like chromosomes, must also be present in pairs. The members of such a pair of factors are known technically as "allelomorphs." Hence, allelomorphs may be defined as the genes that occupy the same position in a pair of like chromosomes. Any one individual, therefore, can not have more than two allelomorphs for any one character in its germ plasm.

If the genes occupying a given locus of the chromosomes of a species are all alike, no hereditary variation in the character governed by those factors is shown. Sometimes, however, internal rearrangements in these genes occur, and once this happens the stage is set for the appearance of a new character in the individuals of that species. These gene rearrangements are known as "mutations."

In some species many such mutations in the genes occupying a certain locus in the chromosome have been known to occur, each giving rise, when present in the pure or homozygous condition, to an entirely new character. Such a series of changes in the genes occupying one locus of a certain chromosome give rise to what are technically known as "multiple allelomorphs." Obviously, more than two members of any such series of allelomorphs can not be present in one individual, but in other individuals of the species the various other combinations are possible.

The inheritance of the blood groups in man is governed by three such allelomorphic factors. The genetic formulae for the various blood groups are shown in the following way.

Blood group	Possible genetic formulae of individuals in each group
O	OO
A	*OA, AA*
B	*OB, BB*
AB	AB

Group O is the recessive group, all individuals of this group being homozygous for gene O which is the ultimate recessive gene of these three allelomorphs. People belonging to group A may have one of two possible genotypes, those homozygous for gene A, or those of the formula AO (heterozygous). Since gene A is dominant over gene O, the blood of an individual of the formula AA gives exactly the same type of agglutination reaction as an individual of the formula AO. Likewise, gene B is dominant over gene O and the individuals of this group are of two genetic formulae, either OB or BB. Gene A, however, is not dominant over gene B so that individuals having the formula AB possess blood which gives an entirely different agglutination reaction than the blood of the other three groups.

As previously noted agglutination occurs as the result of the interaction of two blood elements, the agglutinogens of the cells and the agglutinins of the serum. No blood contains the agglutinins that will cause the clumping of its own cells, so it must be presumed that the factors governing the inheritance of the blood groups in man must control these two reciprocal phases of the blood. Thus, factor O, when homozygous, gives rise to an individual containing no agglutinogens in the blood cells, although the agglutinins in the blood serum of this individual will agglutinate the cells of any other group. Factor A, results in the production of a blood carrying agglutinogens A and serum agglutinins that will cause the cells of both groups B and AB to agglutinate. Factor B, on the contrary, directs the development in a different way, so that individuals carrying this gene have agglutinogens B in their blood cells and the agglutinins in their serum that will cause the clumping of the cells of groups A and AB. And finally, genes A and B acting together produce individuals whose blood cells contain agglutinogens A and B but whose serum contains no agglutinins.

The interrelations of the two phases of this system are not clearly understood. It seems certain, however, that if the inheritance of the blood groups is to be explained on the basis of triple allelomorphs that the same genetic factors govern both phases of the system. Otherwise, some co-ordinating mechanism must be present that would always insure that blood contained no agglutinins for its own cells. Such explanations have been offered, but Snyder[1] has pointed out rather serious objections to them. If the above explanation is the correct one, it might be assumed that the agglutinogens, which are present at birth, are responsible in some way for the development of the agglutinins, since the latter do not appear in the blood stream for several months following birth. A final explanation of these relations must await further analysis.

The older hypothesis, advanced by Von Dungern and Hirszfeld to explain the inheritance of the blood groups, assumed their inheritance to be dependent upon two pairs of genetic factors, the members of each pair residing in a separate set of chromosomes; factor A and its allelomorph, a, carried on one pair of chromosomes and gene B and its allelomorph, b, on a second pair of chromosomes. The various genetic formulae for the four blood groups according to this hypothesis are shown in the following scheme.

Blood group	Possible genetic formula of individuals in each group
O	aabb
A	AAbb, Aabb
B	aaBB, aaBb
AB	AABB, AaBB, AABb, AaBb

The main genetic difference to be observed between the two hypotheses is that group AB contains four genotypes or genetic formulae according to the last hypothesis, while it contains only one in case of the triple allelomorph hypothesis. In both cases it is necessary to assume that the same genetic factors are responsible for the development of both the agglutinogen and agglutinin phases of the blood groups.

The evidence in favor of the triple allelomorphic hypothesis, which is the generally accepted one now, is mainly of two sorts. The first source of evidence comes from a statistical study based upon the actual numbers of the four blood groups present in any population, as compared with the numbers expected. In every race studied to date the agreement between actual and expected is closer for the triple allelomorphic hypothesis than for the hypothesis of independent inheritance. The second line of evidence is from the actual study of the blood groups of children produced from unions of people with known blood types. According to the hypothesis of two independent pairs of factors, marriages between people of group O with AB should give some children in each of the four groups, namely O, A, B, and AB with the majority of the children being in group AB. On the triple allelomorphic hypothesis such matings should produce only children belonging to groups A and B (see Table II). The actual results from a study of many such families confirm the latter hypothesis, it being demonstrated in several of the few cases observed where O and AB children were produced, that these were the result of illegitimate unions.

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[1] L. H. Snyder, "Blood Grouping in Relation to Clinical and Legal Medicine." Williams and Wilkins, Baltimore, 1930.

TABLE II

Blood group of parents	Possible blood groups in children*
O×O	O
O×A	O, A
O×B	O, B
O×AB	A, B
A×A	O, A
A×B	O, A, B, AB
A×AB	A, B, AB
B×B	O, B
B×AB	A, B, AB
AB×AB	A, B, AB

* Calculated on basis of triple allelomorphic hypothesis.

Two other hypotheses have been advanced to explain the inheritance of the blood groups, but neither one fits the facts as well as the two hypotheses discussed. For a discussion of these hypotheses the reader is referred to the previously mentioned book by Snyder.

THE BLOOD GROUPS IN RELATION TO OTHER TRAITS

The relation of the blood groups to other inherited characteristics in man has stimulated much interest among biologists, especially among the medical fraternity. The inevitable result has been that many claims have been advanced that the blood groups show a genetic linkage with certain of the other inherited traits in man. Most of these claims have been unsubstantiated, and many of them, as Snyder has clearly shown, were based upon a misunderstanding of the fundamental concepts of linkage. In no case has the existence of a clear cut case of linkage with any other trait been demonstrated. This is not surprising in view of the relatively small number of inherited characters known for man and the large number of chromosomes. To show linkage, that is a tendency for two characters to stay together in inheritance from generation to generation, the two sets of factors governing the development of the two characters would have to be carried on the same pair of chromosomes. Since there are twenty-four pairs of chromosomes in man it is not to be expected that many such linkages will be found, especially when most of the family pedigrees suitable for the study of a certain human trait do not furnish any data relative to the linkage of this trait with other characters. Obviously, such linkages exist but the methods available are not suitable for their detection and study.

Much study has, likewise, been made upon the blood groups during the course of various diseases. As a result, claims have been advanced that the blood groups were influenced by certain pathological conditions. All of these claims have been questioned by other students and at the present time it may be safely concluded that no definitely proven relations exist between any pathological condition and any one blood group. The blood groups are very constant elements and seem to be little influenced by changes in the physiology of the body processes.

THE MEDICO-LEGAL ASPECTS OF THE BLOOD GROUPS

The medico-legal applications of blood groupings are based upon the fact that a child can not possess an agglutinogen unless it be present in at least one of his parents. Once the blood group of each parent is known it can be predicted in what blood group or groups the children of this pair can belong. Thus, in cases of disputed parentage, the evidence obtained from the blood groups of the persons concerned can never prove that a certain person is the parent of the child in question, but they may show that such a person could not have been one of the parents. The facts are shown in Table II, in which the expected results are given for unions between people of the different blood groups.

From this table it is apparent that if both parents belong to group O the children must, likewise, belong to group O. If one parent belongs to group O and the other to group AB, their children could belong to either group A or group B. In a similar manner the resulting blood groups for all other possible unions are given.

Some exceptions to the expected results from certain unions have been reported, but it is interesting to note that most of these exceptions are found in the reports of the first students of the blood groups. Many of them are probably explainable by faulty technique or possibly by mistakes in the observations of the workers. In some cases, also, the individual in question was definitely known to be the offspring of an illegitimate union. These mistakes are relatively very few when compared with the number of observations that do correspond with the expected results. The only other possible conclusion is that the laws of Mendelian inheritance do not apply in the simple way just discussed to the blood groups. However, since such a large body of facts is at hand that conforms to expectation, it is logical to assume that the errors reported were due to the first two reasons mentioned.

THE RACIAL DISTRIBUTION OF THE BLOOD GROUPS

Anthropological interest in the blood groups arises from the possibility of determining the origin and relationships of the various races of the world through a study of the distribution of the four blood groups in different peoples. The percentage of the four blood groups varies in different races, and the results show that this distribution is to some extent correlated with geographical distribution. Thus, the work carried on by the Hirszfelds shows clearly that the peoples of western Europe contain a larger percentage of individuals of groups A and O. The A and O groups decrease in relative frequency as one moves eastward, while the percentage of the B group increases in frequency. Some idea of the distribution of the four blood groups in the various races may be obtained from Table III.

TABLE III

Location and nationality	Percentage distribution of the blood groups[1]			
	O	A	B	AB
Western Europe—				
English	46.4	43.4	7.2	3.0
Dutch	42.0	44.0	9.0	5.0
Germans	38.4	43.2	12.9	5.4
Swedes	38.1	47.3	9.3	5.2
French	43.2	42.6	11.2	3.0
Americans[2]	44.3	40.4	11.2	4.1
Eastern Europe and Asia Minor—				
Russians	33.4	35.9	22.3	8.3
Turks	36.8	38.0	18.6	6.6
Moslem Arabs	33.8	36.8	18.5	10.8
Arabs	43.6	32.4	19.0	5.0
Eastern Europe—				
Japanese	29.5	39.0	21.3	10.0
North Chinese	30.7	25.1	34.2	10.0
South Chinese	31.8	38.8	19.4	9.8
Indians (India)	31.3	19.0	41.2	8.5
Australian aborigines	56.4	38.0	4.4	1.2
Madagascans	45.5	26.2	23.7	4.5
Americas—				
North American Indians	78.7	19.0	1.9	0.3
South American Indians	82.9	12.8	4.3	0.0
Eskimos	80.7	12.9	24.0	4.0

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[1] Calculated from data tabulated by Snyder, *loc. cit.*, and L. Hirszfeld, "Konstitutionsserologie und Blutgruppenforschung." Julius Springer, Berlin, 1928.

[2] Largely of Western European origin.

Among the peoples of western

Europe and their descendants, as shown for English, French, Germans, and Americans, the percentage of both blood groups O and A is high, while in eastern Europe the percentage of the O and A groups has decreased relatively. In the people long inhabiting the Americas before the advent of other peoples, the North and South American Indians, the proportions of the four blood groups are entirely different from those observed in Europe and Asia. In the American Indians group O is by far the largest while groups B and AB appear very infrequently.

In view of the percentage distribution of the blood groups observed in the various races it might seem that group O was the original group present in all peoples. Then at some time in the past history of the race the mutation resulting in group A appeared, and this became widely distributed among most of the peoples of the world. Its higher incidence among the peoples of Western Europe, however, would indicate that it probably first occurred among the people from whom the present inhabitants of Western Europe descended. The higher percentage of people of group B in Eastern Europe and Asia indicates that the mutation resulting in group B probably arose at a somewhat later date than the A mutation and probably in the people inhabiting western Asia or Eastern Europe.

In the Americas it appears likely that mutation A has occurred at a relatively late date in the people inhabiting these areas, and that mutation B has made its appearance very late, if at all. It is more likely to be accounted for among the native peoples of the Americas as a result of race crossing with the Europeans.

Racial migration and crossing would of course greatly influence the distribution of the various blood groups among different races; and since racial migration and crossing have taken place extensively among the peoples of the world for long periods of time, the racial distribution of the blood groups does not furnish as suitable material for a study of racial origin and relationships as might at first seem to be the case. The only advantage of the blood groups over other hereditary traits for anthropological studies would seem to be in the fact that in case of the blood groups no conscious selection for the various types is possible.

THE GLORIFICATION OF PARASITISM

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It is an ancient custom for philosophers and sociologists, who know little about parasites, to refer to certain persons and groups as parasites on society. It is only fair that the parasitologist, who knows little about philosophy and sociology, elaborate this theme as one who is familiar with zoological parasitism. From a quarter-century's experience with parasitic Protozoa, tapeworms, flukes, nematodes, mites and parasitic insects, there may be derived certain analogies between these parasites and our social parasites, and from these analogies one may conclude—what one wishes to conclude.

All parasites, from the pallid tapeworms to bright-colored tropical ticks, from the burrowing mites to the swift-darting horse-flies, and from the microscopic malarial crescents to the huge hydatid or the giant kidney worm, have this peculiarity in common—that they feed on living animals larger than themselves. On the basis of food habits, parasites stand in contrast with three other groups of animals. One group is composed of scavengers,—the sedentary oyster, the plaintive sea-gull, and the skulking jackal, the eaters of others' leavings and the camp-followers of decaying death. A second group is composed of predators—the hairy tarantula, the destructive pike, the crushing boa, the swooping eagle, and the fierce leopard, the shrewd and powerful killers of prey. A third group is composed of the more or less peaceable animals that work for a living—the insect-eating birds, the grass-eating sheep, the tree-feeding giraffe, the animals that rustle a living by the industrious collection of large amounts of such small provender as grass and grasshoppers.

The reader will have foreseen the sociological implication of this grouping. The terms used are old and familiar in zoology and in the everyday affairs of life. Most of them originated as terms applied to people, and were later applied to animals other than man. For man is an animal, even though he is prone to overlook that fact and prefers to regard himself as an immortal soul. No question is raised here as to the soundness of his high regard for himself as an immortal soul, but from the standpoint of zoology we are now considering the animal that Linnaeus named or misnamed *Homo sapiens.*

This animal has been said by some philosophers to have, in common with other animals, two great driving forces, hunger and sex. We are not concerned at this moment with sex, but we are concerned with hunger, the need and desire for food. As man solves his food problem, which by expansion is the problem of making a living, so he classifies himself for our purpose as a scavenger, a worker, a predator or a parasite. It should be repeated at this point that these comparisons which are given here are mere analogies, but analogies are sometimes of interest and value, as are fairy stories and parables. They are not even new analogies; the ancients saw them and applied similar animal names to certain men, and names of human groups to certain kinds of animals, on the basis of certain characteristics in common.

Our solution of the problem of making a living in this bewildering world is not always in terms of a conscious selection of a life as scavenger, worker, predator or parasite. Life is not that simple, decisions are not that conscious, and our control of events is usually much less certain. Nevertheless, the mental processes corresponding to such conscious selections are usually present.

The person of feeble will or unhappy circumstance, dominated by the fear of life, or ignorant of the ways of making a living, raised in many cases in the wretched environment of squalid poverty, and thoroughly beset by an ingrained inferiority complex, may select a scavenger's life without consideration of any other possibility. He lacks the hustle or ability of the worker, the courage of the predator, and the ambition, even the aspiration, if you please, and the opportunity of the parasite. He lives, in effect, on the rejected leavings of others, and he and his kind constitute a small group; we hope, a decreasing group.

Most of us elect or are forced into the rôle of workers, the common and simple solution of the business of obtaining food. We have at least a reasonable capacity for hustling a living and we concur, outwardly, in the premise that life is or should be an affair in which we exchange with the world a *quid pro quo* for our living. It is fortunate for the scavenger, the predator and the parasite that the bulk of humanity goes into the group of workers, for the worker furnishes the food on which these others feed. His sweat and toil and industry convert the raw material of earth into food for himself, crumbs for the scavenger, and feasts for the predator and the parasite.

The predator not infrequently shows signs of having frankly reacted violently and unfavorably to the idea of earning a living by exertion, the dull, unromantic and unadventurous business of being a worker. In the lower brackets of society he constitutes the recognized criminal element that exercises its craftiness rather than its muscles, and its wits rather than its intelligence. In the higher brackets of society he constitutes a criminal element that is being more and more recognized as exercising a vicious political and financial force. In their immediate relation to the individual and to the small groups on which they prey, these persons are predators, but in their relation to society and the body politic they might be called parasites. To their victims they are tigers; to society they are lice.

And this brings us to a consideration of the social parasites great and small. Here are those who "toil not, neither do they spin," yet who have comfort, luxury and glory beyond those of Solomon. Here are those who have ambitions beyond scavenging, who have a distaste for work, and who may lack the courage, and in many cases have no need for courage, to pit their wits or brawn against the world as predators. Here are the quacks, the shysters, the fakirs, the wastrels of high and low degree, and here also are many persons of the world's elect, persons who are highly regarded and envied. Some are here by inheritance, election and choice, and some by accident. Some are the products of our curious mental processes, our economic absurdities and our legal fictions. By and large they are a motley group, with this in common, that they do not repay from their own life and living in sound values to the world what the world of yesterday and to-day has given them. Even society itself may play the parasite, and take from its men of genius and its unfortunates without recompense and without recognition.

The youngster who faces the problem of making a living, the broad problem of hunger, will consciously or unconsciously take into consideration the attitude of society towards the groups who have solved this problem in various ways. He will know that society will despise or pity the scavenger, and he will not elect that status; only great personal lack and need will put a man in the ranks of the beachcombers. He will note that the workers respect themselves and their kind, but he will also note that by and large they are none too well satisfied with the status in which they are established. He will detect the fact that while labor is of recent years not spoken of, even in good society and in ecclesiastical circles, as the curse of Adam, there is, nevertheless, a wide-spread and urgent desire for a status in which one may truthfully say: "I don't need to work another day in my life." A little further scrutiny would bring him to the astonishing conclusion that parasitism is highly thought of in practically all circles of society, and that the parasites are the most highly esteemed of the groups we have named.

That the predators are not a more attractive group follows largely from two things: First, their activities are too obviously and crudely antisocial, and the hand of society is raised against them; second, it takes a certain amount of courage of a sort to be a predator, and the psychologist's quest of the phobias leaves the impression that courage of all sorts, physical, mental and moral, is a rare thing in the makeup of man. Psychology has shed some light on our composition and motivation by showing us the extent to which we are dominated by our fears, but it has shed little light on the problem of how we are to overcome fear and develop courage in adults with their established patterns of behavior. The courage of the human predator is not a very admirable thing, viewed from all angles, and it is perhaps fortunate that this particular brand of courage is not more common. But if the workers of society had more courage of other sorts there would be fewer predators, for the predator's courage, or courage of any sort, can not well be met and matched by fear of any sort.

And so we come to the conclusion that of the various modes of living, parasitism, the life of large income without effort, life without a demand for work, or for a *quid pro quo,* or for courage, is the most highly esteemed. The parasitic worms have set us a bad example, and from the Protozoa up there has been the innate urge in animals to give up the struggle for existence by the escape to the ease and safety of parasitism; and man has followed these examples and yielded to his innate animal's urge to parasitism whenever possible. Is this an exaggerated statement? It would be reassuring to know that it is, to know that in the majority of persons there is not the desire to shirk the struggle for existence, that the majority of persons desire to repay to the world a just *quid pro quo* for the food they eat and the clothes they wear, that the majority of persons are too ambitious, too proud, too honest and too independent to live by the labor of others, but the evidence does not support the idea. The suspicion remains that the fat and flabby life of the parasite, the toilless existence of the tapeworm, fascinates us.

Here is the escape from life with its uncertainties. In a small way we are beginning to tag the persons who elect to escape from life by the route of chronic, needless invalidism, or conscienceless demands on charity, or suicide. In a large way we should realize that the path of choice, the select and favored route of escape from life's struggles and difficulties, personal, financial or otherwise, is the path to social parasitism. We should realize that much of what is taught and urged as ideal, as the ultimate good, by highly thought-of persons in high places, may be translated in the language of biology as the glorification of parasitism.

In defining a parasite we used its habitat and food habits as a basis, and we have considered certain social analogies in connection with hunger, food and the business of making a living. It so happens that the food habits of parasites are closely related to another basic essential of life—the necessity for reproduction to maintain the species. The reproduction of parasites is a gamble. The parasite plays the law of chances on the basis that if you lay enough bets some of them will win. To maintain a certain species of ascarid, the female worm may produce 30 or 40 millions of eggs. Almost 30 and 40 millions of these eggs will die and go for naught, but it needs only some small fraction of one per cent., say 10 to 100 eggs, to get back to a suitable host and mature, and the perpetuation of the species is assured.

This enormous and wasteful production of eggs is made possible by and correlated with the easy life of parasitism. The ascarid lives in its host's intestine, where it is maintained at a constant temperature, free from the necessity of seeking shade to keep cool or hustling around to keep warm. It is surrounded by food and probably need not, perhaps can not, exercise an effort even at selection of food. Thus provided with a highly nutritious metabolic intake and freed from the need for exertion, the ascarid can devote its energies almost entirely to reproduction. There is the odd chance, so far as ascarids are concerned, that in a host animal there may be no male ascarids to mate with the females present, or *vice versa,* and some nematodes, and almost all tapeworms and flukes, write off this chance by the development of hermaphroditism or parthenogenesis. These parasites are gamblers, but in nature, and without the intervention of man, they usually play a sure thing to win.

It seems then that in addition to their simple solution of the great problem of food, the parasites have successfully solved the great problem of sex. It is a thoroughly dispassionate solution and in complete agreement with the best ecclesiastical doctrine, with the sole object of multiplying and replenishing the earth with their kind.

Can we now draw any sociological analogy? Possibly, but not a too close analogy. Our social parasites do reproduce their kind, but not prodigally. Nevertheless, it is still true that the fat and easy life of the parasite more or less automatically leads to emphasis on sex. The struggle for existence on the part of the worker is still a form of sublimation of the sex instinct, not too complete, but nevertheless a compelled consideration of many things other than sex, many of which considerations do not trouble the parasite.

Looking further into the interesting aspects of parasitism, we may speculate a bit on the effects of parasitism in evolution. Parasites in general exert an injurious, but rarely a deadly, effect on their hosts, and host animals react by a defense mechanism or establish a tolerance for their parasites. In the long course of evolution the interaction of these parasites and host effects must surely have brought about profound changes in both parasites and hosts.

That animals once non-parasitic have taken up the easy life of parasitism, with the resulting degeneration and simplification of certain structures, such as some of the specialized sense organs, and with the resulting excessive development of the sex organs, is obvious enough. Entire groups, such as the tapeworms and flukes, have become so modified by parasitism that speculation as to their ancestral relationships with any existing non-parasitic groups has led to no generally accepted theories. Innumerable nematodes have abandoned the life of their free-living relatives in soil or water and gone the easier way of parasitism. In so doing they have undergone profound increases in size. Fattening at the expense of their hosts, there are but few, if any, of them that have not outstripped their free-living relatives which are usually not over a millimeter long. The giant of the parasite group, the dog kidney worm, is a yard long and as thick as one's finger, or 900 times as long as its probable nematode ancestor, and many thousands of times as bulky. Thus we see how the parasite waxes fat.

Parasites wax fat at the expense of host animals that grow thin. For parasites affect their host animals unfavorably, and the commonest effect produced is what we broadly term unthriftiness. Now unthriftiness involves malnutrition, stunting and diminished growth. This effect of parasitism is most marked in young animals. Stunting through the growth period of youth leaves a permanent effect, since mature animals can not make up for failure to grow when young. The damage wrought by parasite toxins probably involves the endocrine system, and all this results in subnormal animals. This parasitism is ubiquitous, present in most animals in almost all places and at almost all times. The parasitized animals in subnormal condition do not produce as good stock as they might have produced otherwise. It calls for no great stretch of the imagination to visualize parasitism as one of the dwarfing factors that have held animals to their present size, and to conceive that without the development of this fatal and fascinating habit of parasitism the elephant to-day might be a better elephant and the mouse a bigger mouse. Civilized man is growing taller, possibly in part because civilization sets up insuperable barriers against most of man's parasites.

Parasites grow fat at the expense of host animals that grow thin. Is this true in sociology as in zoology? Has it a bearing on poverty, unemployment, hard times and other economic ills? Does food come to the tables of lifelong idlers by magic or by parasitism? Do millions go hungry because there is too much wheat, or in rags because there is too much cotton, or are these host animals clinical cases of social parasitism? Sociologists, economists or the reader may answer the questions.

Meanwhile, what defenses have host animals developed against their parasites? For one thing they have developed a tolerance for them, the ability to survive, as a rule, even with the double burden of feeding themselves and a horde of worms that not only feeds off them but in other ways injures and insults them. There is good reason to suppose that the large size of the liver in many vertebrates might be in part a response to parasitism. In some animals two thirds of the liver may be destroyed without visible bad effects on the animal. This suggests a large margin of safety in nature's specifications for livers, and may be correlated with the fact that poisons and parasites leaving the digestive tract by the portal system of the blood stream encounter first of all the efficient filter of the liver and work here their first, and sometimes their only, damage. Here many chemicals work their injury, and here many parasites are entrapped or destroyed. It seems highly probable that our oversize livers are in part a defense mechanism against parasitism.

The human hosts of social parasites have also their defense mechanisms. They too have developed tolerance and capacity for insult and injury. They too have the ability to support themselves and their parasite burden, and survive. Survive? Nay, verily, to enjoy and approve.

We may view parasitism, as many have viewed it, as an escape from the struggle for existence. But if we have represented the tapeworm as an object of scorn because of its parasitic habit, we have been misrepresenting the case and we have not been facing the facts. Some one, probably Karl Marx, a person looked on with disfavor in the best social circles, once stated that every one is either a worker, a beggar or a thief. He might have put the matter less baldly and more charitably by speaking of workers, scavengers, parasites and predators. Put even in that rather bald and blunt fashion, one would feel inclined to be a worker. But put with just a bit more delicacy and finesse, put, for instance, in the form of an offer of a substantial assured income for life, with no further need for work, the vast majority of us would unhesitatingly elect the life free from care and worry—and work.

In other words we are fascinated with the life of parasitism, and, given the opportunity, we would choose parasitism. Perhaps this is the wise and philosophical thing to do. Perhaps the best of all possible goals of endeavor is a world without work. High authorities of various sorts have spoken with approval of the cultural value of unbroken leisure, of the happiness of the South Sea Islander, who does not exert himself beyond the exertion of eating, and of the beauty of rest and meditation without regard for the hurry and hustle of the world.

It seems as though the defeatist program of the parasite was our ideal and the preferred solution of the business of living for most of us. To secure a favorable balance of intake over expenditure we grasp the soft and easy solution of parasitism, with the parasite's minimum expenditures and with a host's contribution to intake. Psychologically, life has us beaten. Only the energy of a Roosevelt will develop a Rooseveltian eagerness for "the strenuous life." Under the lash of necessity we will work, and if we must work we may even find work a pleasure, but let an avenue of escape open up through which we may flee from labor to ease, from hard uncertainty to soft certainty, and we hasten to take on the comfortable life of the parasite.

Man begins his life as a parasite of the maternal body, and his first reaction to the free life is a wail of protest. From the child's desire for the wishing ring or Aladdin's lamp to the adult's hope of inheritance or of quick wealth in a gamble or speculation, parasitism is the heart's desire of man. Even in death he has the expectation of heavens of idleness tempered to the Christian by music and to the Mohammedan by houris. The successful parasite may expect congratulations and envy—not condemnation. His success will mark him as foresighted, or fortunate or sagacious. He may or may not be a mere, flaccid, human tapeworm, but if he is he will be termed a gentleman of leisure.

It is true that one finds here and there rare and peculiar individuals who are scornful of parasitism, who abhor and even reject the secure and sheltered life when it is offered them, but it is probable that these few odd characters present physiological and mental peculiarities. They may feed on such food as other mortals, but their intake seems to be rather efficiently utilized to develop physical energy sufficient to meet life whether it come with a job or a fight, to develop mental energy sufficient to deal with life as a perplexity and an uncertainty, and to go unshaken through the disillusionment of life, to outgrow the love of toys and trinkets, the love of wealth and ease, and the love of fame, applause and approval, to find life interesting when faith and proven certainty alike prove unattainable, and to walk with a high head towards man's unavoidable destiny in death.

One is tempted to toy with the idea that the breeding of persons of this sort might be encouraged, with the idea that perhaps they could in some way be used in larger numbers. At first blush they would seem to be the ideal workers, but actually they do not fit into any category to the world's satisfaction. The worker in general, manual or intellectual, subscribes to our generally accepted doctrine of parasitism as an ideal. So long as he must be a worker he will serve as host to innumerable parasites, always with the understanding that in a country of opportunity for all he is permitted at the first opportunity to exchange his rôle of host for the rôle of parasite. Such workers are the dependable support of a society that glorifies parasitism. But these odd persons who reject the philosophy of parasitism will not serve willingly as hosts, nor live happily as parasites, nor sustain and subscribe to our philosophy of parasitism as the highest good. In a world which envisages an eternity of heaven as endless rest from toil and labor and trouble, these odd persons with their fondness for physical and mental activities, their desire to apply to every one the scriptural injunction to eat one's bread in the sweat of one's brow, their eagerness to grapple with life and its problems, are out of place. To adopt their philosophy on a large scale would be to overthrow much of our social structure, and the man who is opposed to social parasitism must be frowned upon as dangerous, for the state, the church, business and society believe in parasitism as the ideal of this life and the next.

Is this unkind or unfair? I think not. In a world in which parasitism, under more euphonious names, is so highly regarded as a form of freedom from the uncertainty and complexity of life, a world which pessimists critically regard with jaundiced eye as probably the best of all possible worlds, a world which both church and state to-day are more prone to view with alarm than to point to with pride, it has been said that one may elect to be the horse or the rider. One loses in public esteem and gains little in one's own self-esteem by electing to be the horse.

In spite of all this, some will agree with Wheeler that biology teaches us this categorical imperative: Do not be a parasite or a host, and try to dissuade others from being parasites or hosts. It may be—we shall not be here, so it will not matter to us—that some day social parasitism, life at the expense of others, may come into disfavor. We trust that in that event we shall have a safe and smooth adjustment to the now alien idea that all persons, meaning by that, all, should justify their existence by an adequate return to society for their share of society's contribution to them, and that there will be no occasion for the use of drastic and dangerous anthelmintics and insecticides in the treatment of present-day social parasitism. Before that day the economist and sociologist have a long educational program ahead of them if they are to persuade the man on the street that the legal exchange of money for the necessities and luxuries of life is not necessarily the giving of a *quid pro quo* for our living.

When, and if, that time comes, society may elect to apply the surgeon's scalpel to its hydatids, to take such drugs as will remove its tapeworms, to comb the lice from its hair, and to oil the ponds where its mosquitoes breed. Let us pray that the parasitologist who prescribes control measures for social parasitism may be sagacious. Zoologically, a world without its animal parasites would be a very different world from the world of to-day. Sociologically, a society without its human parasites would be a very different society from the society of to-day. Whether a world or a society without parasites would be a better world or society is another question. Intellectuals who believe that culture can grow only on a soil tilled by helots will elect a parasitized society, with themselves as parasites. Religionists who believe that society should attend to their physical needs while they devote their lives to the saving of their meager souls will elect a parasitized society. The idle inheritors of wealth will elect a parasitized society. Politicians who serve themselves and their friends from the cafeterias of national, state or city funds will elect a parasitized society. These groups will seek in the name of art to save the ticks for their gay colors, in the name of culture to save the fleas for their ingenuity, in the name of religion to save the tapeworms for their tranquility, and in the name of humanity to save the mosquitoes that have come up from the dismal swamps to the glory of flight on gossamer wings.

All these may be right. In any case, let us look the facts in the face: We love and adore parasitism. We must admit it. Shall we continue our adoration? Will it lead us to our heart's desire of a world without work, or will it fasten on this man the inescapable rôle of parasite and on that man the unavoidable rôle of host? Will it ultimately destroy us in some future when a too heavy burden of parasites kills their hosts and a lack of hosts leaves the parasites to perish? Or shall we confront this adoration of parasitism and declare it outmoded? Shall we face the fact that life is and will long be a struggle for existence, that the longing for escape from that struggle is the stigma of the physical and mental weakling, and that the free man can not live the life of parasite or host? Shall we vote that in the incessant fight of man against nature's inexhaustible armament of weapons of frost and fire, of flood and famine, of pain and suffering, of disease and death, all men must bring to that fight an energy unweakened by the soft life of the parasite or by the sapped vitality of a host?

At this point we would bring out one important difference between animal parasitism and social parasitism. Although innumerable species of all sorts of animals have given up the free life for the life of parasitism, apparently no obligatory parasite has ever given up the parasite's life for the free life. It seems impossible for the true parasite to beat back to the free life or to retrace the steps of its degradation.

The case is not so bad for the human parasite. History and literature present many cases of the pathos and tragedy of the human parasites that have been ousted from their parasitic environment. Too often these unhappy mortals, fallen from their high estate as parasites, have been able to find for themselves only a scavenger's lot as beggar, beachcomber or hanger-on, tragic or pathetic figures of broken men and women, as incapable of dealing with life as is a tapeworm removed from its host. But in even more cases the human parasite has shown the extraordinary capacity for adaptation which has characterized this human animal that wanders from the tropics to the poles, that beats a path from the ocean to the mountain peaks, that stops at no barriers of height or depth, of fire or water. Unique in these respects, he is also unique in the ability of the human parasite to fall from a feather-lined nest, land on his feet, and start in pursuit of such grasshoppers, worms, suckers or berries as may come to hand or be sought for as desirable in lieu of his lost sustenance. This is a hopeful feature of the problem of social parasitism. The human parasite remains a facultative parasite. Given a generation of propaganda and the education of the young along selected lines, even his innate desire for parasitism may be definitely submerged under a substituted set of other desires, possibly even a desire for work.

INSECTS IN ENGLISH POETRY

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Bugs in Books

The Land of Literature constantly allures. I slip away from the irksome tasks of a prosaic world to make little excursions into its inviting borders. Sometimes the road irresistibly beckons, and I go on and on for a long time playing truant from duty. Again, the wanderlust seizes me in all its power, I cast everything aside, and go on prolonged journeys into the interior of this fascinating country.

For many years I abandoned myself to the delights of the journey, keeping no diary and collecting no souvenirs. I was content to luxuriate in memories ever blowing from those enchanted shores, as breezes refreshing the sultry air of a monotonous day and enhancing the atmosphere of a glamorous night. Then fellow travelers interested me in their mementoes. Many had become connoisseurs, some having acquired a galaxy of favorite portraits, others of landscapes, from the great galleries of literature. Many had made notable collections of birds or beasts or flowers. Finally, I, too, became imbued with the spirit of the collector. But what should I collect? The most widely known regions in the Land of Literature had been exploited by many travelers, some of them in a spirit of vandalism overrunning even the private domains of the most famous. Again I inspected the collections of travelers and to my surprise found but few specimens of insects. Surely these little creatures, so numerous in our own country, abound in the Land of Literature. Immediately I decided to go in search of them.

I equipped myself with all the paraphernalia of the entomologist. As a miniature collecting kit I purchased a little notebook. For nets I secured many kinds of concordances. Some of these nets were of such coarse mesh that they would contain only the larger insects, allowing the smaller to slip through unnoted. Others were of fine, closely woven fabric, but the entrapped insects cleverly camouflaged themselves under pseudonyms and were thrown out as worthless.

My field glasses were powerful books of quotations. Standing upon some vantage ground, I could look through these glasses and sight the insects hovering over great stretches of territory. When the insects observed especially interested me, I would travel far to hear the cicadas sing from inviting nooks in Theocritus' verdant pastures or to watch the bees swarm among Emily Dickinson's thick hives.

It was with a feeling of trepidation that I completed arrangements for my undertaking. The evolution of the usual entomologist from a conspicuously bespectacled, absentminded bug chaser into a dignified scientist commanding both the respect and the coin of the realm has long been a notable example of complete metamorphosis. Not so with the literary entomologist. Requests for assistance for my enterprise were usually answered by a doubtful shake of the professorial head or ill-concealed ridicule from my fellows. Now, explorers who have traveled into the deepest recesses of literary jungles in search of birds and beasts have not only escaped all storms of derision but have been lauded as sportsmen. But to go ogling about for bugs in books! The guilty one must be a veritable book-worm, some inferior species of the *Psocidae*. But who does not cherish the spirit of the pioneer. With an unshaken faith I sailed out over tractless seas. Rich treasures have been my reward.

In planning my explorations into the Land of English Poetry, I mapped out a tour that would carry me to old taverns enshrouded in a mist of tradition, to the radiant courts of the Renaissance, and to the flourishing soils of newly chartered fields. Into a tour of brief duration I crowded an itinerary including excursions to vast estates belonging to those long since crowned with fame and also to the fields of new settlers still breaking soil. On some of these excursions I carried great nets and field glasses, on others I took only a little collecting kit into which I dropped choice specimens.

The common belief that one finds what he is looking for proved true in my case. I was looking for insects on all my travels and to me they were the most conspicuous and important objects on the landscape. In a very literal sense I would "strain at a gnat and swallow a camel."[1] I imbibed something of the spirit of Conrad's Bavarian who, in an absorbing narrative of his capture of a gorgeous butterfly, referred to a murder he was forced to commit as a mere incident and to the capture of his insect as the all-important event of the day. I would travel down long roads of tragedy, and if no insect crawled across my path, I would return with a sense of futility, with nothing of that buoyancy of spirit that is supposed to follow the Aristotelian prescription for jaded spirits. Again, I would go sailing across seas of mirth, but when I landed, unless insects had fluttered around the boat, I cried out with the psalmist, "All is vanity!" But if insects were there! Ah, that was a different story. I returned with the air of a conqueror bringing in the rich spoils of victory.

Whether snatching at an occasional fly while journeying down the highway with Chaucer's pilgrims, or swinging a great net while treading Shakespeare's broad open fields or delving into the mysteries of the glades and forests of his vast estate; whether painfully caging the stinging insects that buzz in the torrid atmosphere of Pope's domain, or lazily coaxing the winged creatures that drift in the intoxicating sweetness of Shelley's garden—always I felt the pride of a connoisseur in my collection.

The poets were ideal hosts. In fair weather or foul, summer or winter, they escorted me down the long roads or the alluring byways of their estates to show me the objects of my search. Whether we chatted around the fireside in the blustery coldness of a winter night, or walked in the crisp freshness of a spring morning, or rested beneath the trees in the heat of a midsummer noontide, or strolled in the golden glow of an autumn twilight, my hosts obligingly discussed my favorite topic. Not only did they tell charming stories of the insects living among their own flowers but retold many fascinating tales of those belonging to bards of distant lands, far in time and space from their native shores.

I suffered the disillusionment common to all travelers. Sometimes in following bright insects down the pathways of gardens I had imagined wholly beautiful, I splashed into puddles of putrid, stagnant water. Sometimes, in chasing a rare insect through labyrinths of dense, tropical beauty I would stumble unawares upon decaying offal. But for the disappointing discovery that perhaps the loveliest gardens and the most beautiful estates always have little rubbish heaps, I was compensated many times over by the unexpected delights of every excursion.

As a traveler returning from a far country, I have brought these souvenirs.

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[1] Matthew, 23: 24.

They are not intended to replace a visit but merely to encourage you to explore for yourself the marvels and beauties of the varied insect regions in the Land of Literature. The butterfly fluttering in the narrow confines of my insectary can but suggest the beauty of the butterfly flitting unhampered against a background of rainbow-hued flowers in Keats' garden. The beetles, stilted and cold in my exhibition cases, arranged as they are by the crude hand of a novice, can but poorly hint at the fascination of the flashing creatures that dance and glimmer in the sunlight among Francis Thompson's exotic bowers.

Some insects the poets have segregated and nourished from the rich nectar of a favorite flower of thought until they have developed into creatures of surpassing beauty. These I have seldom taken from the poet but have chosen instead specimens from more numerous varieties that sipped the nectar of many flowers and often were all but hidden in a profusion of blossoms. The specimens I shall show you were not selected as being typical or representative of any locality. From a poet who had many, I sometimes chose few, and *vice versa*. I wish only to give you some idea of the great variety of insects and their amazing adaptability to any environment in the infinitely varied regions of the great Land of Literature.

METAMORPHOSIS

In the childhood of the race the bug was among those half real, half imaginary terrors that freighted man's waking moments with a sense of excitement and apprehension and startled him from slumber with a cry of fright.

Right as the humor of melancholye
Causith many a man in slepe to crye,
For fere of beris (bears) ore of bolis (bulls) blake,
Or ellis that blacke buggys wol him take.

—*Chaucer, "Nun's Priest's Tale," 1, 116.*

So persistent was the association of bugs with hobgoblins and specters that bugbear has become synonymous with anything causing terror. Because of the imaginary character of the associated evils, the term is particularly applicable to those things causing needless fright.

As the race has become more sophisticated, superstitious fear of bugs has vanished along with the dread of ghosts and specters. However, the scientist, who is chiefly responsible for banishing specters of all kinds, has brought little relief from the terror of the bug. With all the miraculous instruments of modern invention at his command, he has with a seeming wizardry cleared the air of superstition. Yet he has replaced an imaginary fear by a scientific reality. Primitive man could cherish the hope that bugs might not be so terrible as he feared. Any faint hope of modern man that his fears may be groundless is shattered by a battering ram of incontrovertible facts bolstered up by profound theories.

Bugs with their aura of spooky associations flourished in the time of fairies and elves. This season past, they wound themselves into cocoons and went to sleep. When they emerged in the springtime of scientific investigation, behold, they were more terrible than before. Viewing them in the clear sunlight of fact, through eyes whose power of penetration is greatly manifolded, man need no longer have illusions about the bug. He has learned of a certainty of the unmistakable power of the bug which disappeared as a bogey to return as an actual and formidable enemy, reinforced with the means of destruction, all the more to be dreaded because his weapons dealing pestilence, disease and death are discernible only to the keen eye of the scientist as he searches them out with powerful lenses.

The scientist, speaking in a voice

ringing with the authority of the prophetic messages of old, warns of imminent danger from the enemy. The people rally to the defense. They continuously pour into the coffers of the nations of the world a great stream of gold. More and more of them enlist as new recruits in that great army of soldiers who go out to fight in the front line trenches. Yet all their efforts have but temporarily checked the advancing forces. The changing conditions of retreating mankind have but rendered more effective the weapons of the enemy. Not only has the enemy augmented his forces with an alarming arithmetical progression, but from each successive instar he has emerged more terrible than before. When his metamorphosis is complete, who can doubt that he will find a place in the epics of the future (if he does not completely annihilate mankind, as some with wavering confidence prophesy) comparable to that of the dragons and monsters in the epics of the past.

PLAGUES

It is only in the realm of childhood that the old shadowy, and perhaps instinctive, fear of bugs still persists. Spenser speaks of "bugs to fearen babes,"[2] and one of Eugene Field's little heroes boasts, "I ain't afraid uv snakes, or toads, or bugs, or worms or mice."[3] Dismissing a threat, Petruchio exclaims," Fear boys with bugs."[4]

The insect frequently, and fortunately, presents a less formidable aspect. He may take an elfish delight in annoying man, as the mosquito which disturbs his slumber, or the fly that returns with a devilish persistence to the most ticklish spot on a bald head. Across the pages of his famous diary, lice crawl dangerously near the crowned heads Pepys so closely and irreverently inspects. Presumptuous fleas divert his attention from the engrossing news of court scandal and bring down his wrath and his fists upon the careless maids who failed to search his bed carefully enough to insure his comfort. Though he displays an uncontrollable temper when fleas attack him, he hugely enjoys jesting with a companion of the night who was strangely singled out by the fleas for their exclusive attention.

> We lay very well, and merrily; in the morning, concluding him to be of the eldest blood and house of the Clerke's, because that all the fleas come up to him, and not to me.

To Aristophanes bedbugs were so pestiferous that the most felicitous abode his imagination could picture — in fact, heaven—was a place made up of "ports —streets, hotels, where bedbugs are most scarce."[5]

Though man may be feverishly excited while the victim of an annoying insect, his "emotion recollected in tranquillity" often finds an outlet in an amusing parody or jest. Thomas Hood evidently obtained enough pleasure from "The Cannibal Flea" to compensate him for a night's unrest.

It was many and many a year ago,
  In a District styled E. C.,
That a monster dwelt whom I came to know
  By the name of Cannibal Flea
And the brute was possessed with no other thought
  Than to live—and to live on me.

Scogin perhaps felt that he was amply remunerated for any personal inconvenience by the money and the fun he obtained from selling the old wives a powder concocted from rotten wood, which he claimed, with all the seriousness of the modern salesman, was effective for killing fleas.[6] It may have been in the spirit of the wife of one of the

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[2] Spenser, "The Faerie Queene," Canto 12, St. 25.

[3] Eugene Field, "Seein' Things."

[4] Shakespeare, "Taming of the Shrew," Act 1, Sc. 2.

[5] Aristophanes, "The Frogs."

[6] Hazlitt, "Dictionary of Faiths and Folklore."

"American Men of Science," who permitted a conjurer to attempt the removal of her warts, or it may have been in a fog of superstition that the people of the Middle Ages employed the following remedy for ridding themselves of fleas.[6]

> A very easie and merry conceit to keep off fleas from your beds or chambers. Plinie reporteth that if, when you first hear the cuckow, you mark well where your right foot standeth, and take up that earth, the fleas will by no means breed either in your house or chamber, where any of the same earth is thrown or scattered.

From remote antiquity man has regarded the insect as a means of torture to effect retribution in the erring individual or nation. The disobedient Jonah was denied the comfort of his gourd vine, for "God prepared a worm when the morning rose the next day, and it smote the gourd that it withered."[7] Keats, at least in this instance showing symptoms of some of the evils he sets out to correct in others, prescribes the terrible sting of the gadfly as an effective punishment for nearly all misdemeanors.[8]

While it is not known of a certainty whether the worms causing the loathsome diseases of the sufferers in some of the old chronicles were Nematelminthes or the larvae of insects, scientists agree that the accounts might with accuracy refer to the larvae of certain insects. In his story of the wrath of God against a wicked man, a monk says:

The wreche of God hym smoot so cruelly,
That thurgh his body wikked wormes crepte,
And ther-with-al he stank so horriblely
That noon of al his meynee that hym kepte,
Wheither so he a-wood or ellis slepte,
Ne myghte noght for stynk of hym endure.
—*Chaucer, "The Monk's Tale."*

In a mood of dejection because he feels that life hangs by such a slender thread, Boethius asks:

> For yif thou loke wel up-on the body of a wight, what thing shault thou finde more freele than is mankinde; the whiche men wel ofte ben sleyn with bytinge of smale flyes, or elles with the entringe of creepinge wormes into the privetees of mannes body.
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> *Chaucer, "Boethius," Bk. 11, p. 6.*

Job, in that mighty drama of the whole problem of human suffering, cries out in anguish from his ash heap.

> My flesh is clothed with worms and clods of dust; my skin is broken, and become loathsome.
>
> —*Job, 7: 5.*

Insects have changed the course of human history. Lice and flies sent as plagues to effect the liberation of the Jews softened the heart of a stern monarch whom the wailings and pleadings of an entire people had left hard and obdurate. Before Pharoah would relent

Frogs, lice, and flies must all his palace fill
With loathed intrustion, and fill all the land.
—*Milton, "Paradise Lost," 12: 177.*

Moses must have been acting under the guidance of a friendly providence when he chose as plagues for his oppressors the insects most loathsome to them. To the Egyptians, who took meticulous care of their bodies, the infestation of lice was especially abhorrent. They regarded lice not only as an outrage against bodily cleanliness but as a profanation of the temple if they entered to worship while harboring such vermin. Both the personal habits and the clothing of the priests were regulated by their fervent desire to keep free from lice. "The judgments, therefore, inflicted by the hand of Moses were adapted to their prejudices. It was, consequently, not only most noisome to the people in general, but was no[9] small odium to the most sacred order in Egypt, that they were overrun with these filthy and detestable vermin."

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[7] Jonah, 4: 7.

[8] Keats, "The Gadfly."

[9] Harris, "Natural History of the Bible."

Insects have a prominent place in Solomon's catalog of the worst calamities that can afflict a nation.

> If there be in the land famine, if there be pestilence, blasting, mildew, locust, or if there be caterpillar; if their enemy besiege them in the land of their cities; whatsoever plague, whatsoever sickness there be.
>
> —*1 Kings, 8: 37.*

In Joel's picture of complete destruction and utter desolation, insects assume a terrible importance.

> That which the palmerworm hath left hath the locust eaten; and that which the locust hath left hath the cankerworm eaten; and that which the cankerworm hath left hath the caterpiller eaten.
>
> —*Joel, 1: 4.*

Commentators in general agree that translators have been vague and indefinite in their interpretation of the names of insects in the Bible. There is not always conclusive evidence as to the specific insect intended. Whatever the insect, the effectiveness of the punishment it inflicted is attested by the results obtained.

When directed against foes, plagues are designated as punishments wisely inflicted by a helpful providence. When the situation is reversed and plagues afflict the "chosen" people, they are decried as the unmerited visitation of Satan.

The cricket, descending upon the fields of the pioneer Mormons in such distressing numbers that it withstood both their "faith and works,"[10] is described as having an appearance that "suggests the idea that it may be the habitation of a vindictive little demon." Reserve food supplies had been greatly depleted by a new influx of disciples, and existence itself depended upon the increase of the fields. When the unavailing prayers and ineffectual attempts to vanquish their foes had left the pioneers desperate, great flocks of gulls alighted, driving them into a panicky fear of starvation. They visualized the desolation pictured by Joel when one pest consumed what the other left. Imagine their rejoicing when they discovered that the gulls were not eating the remnants of their crops but were devouring the crickets instead.

The coming of the gulls was interpreted as divine intervention, a miracle, which, though belated, prevented starvation. The gull immediately became a sacred object, protected by legislation, eulogized in song and story, and commemorated in the "Sea-gull Monument." Every means of extolling the gull necessarily includes the cricket. Thus, the insect becomes important in the literature of the people, whether it be hailed as a deliverer or condemned as a pest.

Events of such cataclysmic proportions as plagues recur inevitably in the literature of the people. Already such narratives of the period as Rolvaag's "Giants in the Earth" contain vivid stories of the Rocky Mountain locusts that descended as a great, devastating cloud upon the fertile plains of the pioneers and arose leaving only barren ground. When this catastrophe recedes farther into the realm of the past, it doubtless will take an increasingly important place in the traditionary lore of the country.

Though insects have caused many epidemics of national importance, they frequently have been wholly absent from the literature arising out of the calamity. Sometimes it is not until decades afterward that science discovers the fact that insects spread the epidemic. Had the people of the Middle Ages known that the bite of the flea was responsible for the horrors of the bubonic plague, they probably would have entertained superstitions quite different from their half-mirthful ideas of this parasite.

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[10] Professor Kimball Young, "A Story of the Rise of a Social Taboo," SCIENTIFIC MONTHLY, May, 1928.

When the insect temporarily or permanently thwarts man's most colossal undertakings, he consequently becomes the motivating force back of an interesting literature. The mosquito vehemently slew an enormous army of workers, rendered idle and useless the most ingenious machinery of the world, and thereby balked a nation's plans to construct the Panama Canal. A great army of skilled engineers went out equipped to conquer the Andes and build a railroad into the clouds. However, they soon found that their most formidable foe was not the forbidding mountains armed with gigantic swords of ice, but the mosquitoes that ruthlessly condemned them to death or subjected them to long years of the tortuous dengue fever. The mosquito, a villain of such magnitude that he exacts admiration for his tremendous power, becomes comparable to Satan, who in the enormous scope of his majestic evils in "Paradise Lost" usurps the place of the hero.

When man does not respond to the retributive influence of the scourge of the gods, he is consigned to a hell where his tormentors pursue him to vent upon him their eternal torture. The dreaded gadfly is ordered,

. . . get thee back to hell—
To sting the ghosts of Babylonian kings.
—*Shelley, "Oedipus Tyrannus."*

What more excruciating punishment could be devised than

. . . a red gulf of everlasting fire,
Where poisonous and undying worms prolong
Eternal misery to those hapless slaves."
—*Shelley, "Queen Mab," IV.*

Supernatural beings are not immune to the scourge of insects. The goddess, Io, transformed into a white heifer, was doomed to undergo the harrowing torment of the gadfly.

The Gadfly was the same which Juno sent
To agitate Io, and which Ezekiel mentions
That the Lord whistled for out of the mountains
Of utmost Aethiopia, to torment
Mesopotamian Babylon. The beast
Has a loud trumpet like the scarabee,
His crooked tail is barbed with many stings,
Each able to make a thousand wounds, and each
Immedicable; from his convex eyes
He sees fair things in many hideous shapes,
And trumpets all his falsehood to the world.
—*Shelley, "Oedipus Tyrannus."*

MINUTENESS

Though man quail in terror and helplessness before multitudes of insects, he reverses his attitude in the presence of small numbers of them, frequently scorning them as insignificant. They become for him an effective source of belittling epithets. In rapid succession insects flew from the fiery tongue of the infuriated Kate when she screamed to her unwelcome suitor, "Thou flea, thou nit, thou winter-cricket thou!"[11] Along with the household bric-a-brac the cognomen "insect" descends with an amazing frequency upon the head of Jiggs of comic strip fame. Mutt not only hurls bottles and bricks at the vanquished Jeff but adds verbal bugs to his flying missiles.

Because of its small size, the poet finds in the insect an impressive means of describing things rendered small by distance or unimportant by comparison with things of greater value. Ants are often chosen when great numbers are involved.

The thronging thousands, to a passing view,
Seemed like an ant-hill's citizens.
—*Shelley, "Queen Mab," II, 101.*

In veneration of the Lord, the prophet Isaiah says, "It is he that sitteth upon the circle of the earth, and the inhabitants thereof are as grasshoppers." In his "Hymn to Apollo," Keats in abnegation questions,

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[11] Shakespeare, "The Taming of the Shrew," Act IV, Sc. 3.

O why didst thou pity, and for a worm
Why touch thy soft lute
Till the thunder was mute?

Realizing his helplessness, but resenting his oppressor, the poet protests:

No more, thou thunder-master, show
Thy spite on mortal flies:
—*Shakespeare, "Cymbeline," Act V, Sc. 5.*

When so unimportant as to pass unobserved, man often compares himself to an insect. "I was no more noticeable than an insect."[12]

Then of the crowd ye took no more account
Than of the myriad cricket of the mead.
—*Tennyson, "Lancelot and Elaine."*

The insect appeals to Chaucer most as an expression of insignificance. His little nun says of an unsavory story, "Swich talkyng is nat worth a boterflye." Those who resent the fact that Chaucer calls such a beautiful insect as a butterfly worthless may be appeased when they remember that he also classified the hen, that to-day universally lays golden eggs, as "worthless."

An old book of astrology, an adversary, a charm, the noise of "The Parlement of Foules," are all characterized as "nat worth a flye." The general worthlessness of flies appears in Scotch dialect when Burns writes, "Gang by me as tho' that ye car'd nae a flie," when his Philly says to her poor Willy, "I care nae wealth a single flie," and when his "Country Lassie" sings,

For Johnnie o' the Buskie Glen,
I dinna care a single flie;

The immense diversity of the literary application of the idea of the insignificance of insects may be illustrated in the following quotations which with a striking appropriateness involve the little sonnet and immeasurable eternity.

Tut, tut, your sonnet's a flying ant,
Wing'd for a moment.
—*Tennyson, "Queen Mary," 11: 2.*

Then conquered, thou, eternity, shall lie
Under my hand as little as a fly.
—*James Stephens, "The Lonely God."*

Minute size is not always correlated with insignificance. Little insects swiftly fly to thoughts of dainty, fairy-like things. Only in the silence of seclusion, can the ear hear such sounds as

Seeds in a dry pod, tick, tick, tick,
Tick, tick, tick, like mites in a quarrel.
—*E. L. Masters, "Petit, the Poet."*

Only in the motionlessness of an atmosphere where all things but thought are chained to earth can the imagination hear such music as Hamlet heard when

He sat so still, his very thoughts took wing,
And, lightest Ariels, the stillness haunted
With midge-like measures;
—*De La Mare, "Hamlet."*

An extremely little book of postage-stamp proportions has pages described as

. . . every marge enclosing in the midst
A square of text that looks a little blot,
The text no larger than the limbs of fleas;
—*Tennyson, "Merlin and Vivien."*

What a diminutive little creature to have eyelashes "Not longer than the May-fly's small fanhorns,"[13] or to be clothed as "Wee Willie Gray."

Wee Willie Gray, and his leather wallet,
Twice a lilie flower will be him sark and cravat.
Feathers of a flie wad feather up his bonnet,
Feathers of a flie wad feather up his bonnet.
—*Burns, "Wee Willie Gray."*

Easily does the insect drift into fairyland where he is at home with fairies and elves and gnomes. A cricket is sent on the mission of a mischievous elf to pinch the slatternly "maids as blue as bilberry." Fairies, "Thieves of a guise remotely fair," sneak into the hive and rob the bees of their honey.[14] Titania, in the fascinating delusion of a "Midsummer Night's Dream," commands the fairies that they

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[12] Conrad, "Lord Jim."

[13] Keats, "Oh, I am frightened."

[14] De La Mare, "The Honey Robbers."

The honey bags steal from the humble-bees,
And, for night-tapers, crop their waxen thighs,
And light them at the fiery glow-worm's eyes,
To have my love to bed and to arise;
And pluck the wings from painted butterflies,
To fan the moonbeams from his sleeping eyes;

No more fitting equipage for the queen of the fairies could be devised than that having

... waggon-spokes made of long spinners' legs;
The cover, of the wings of grasshoppers;
The traces, of the smallest spider's web;
The collars, of the moonshine's watery beams;
Her waggoner, a small gray-coated gnat,

. . . .

Her chariot is an empty hazel nut,
Made by the joiner squirrel or old grub,
Time out o' mind the fairies' coachmakers.
—*Shakespeare, "Romeo and Juliet," Act. 1, Sc. 4.*

The gnat as a waggoner and the grub as a coachmaker become admirable servitors of the fairies, but too seldom do the captivating lovers, for whom even the flowers languish, enter the realm of fairyland to become equals of the fairies. The emperor moth in the richness of his royal robes might arouse the envy of the fairy king; the ethereal Chrysopid with gossamer dress of delicate green and headdress of gleaming gold might rival the beauty of the fairy queen. The grotesque little leaf hoppers would delight the elves as playmates.

Naïve delight in fairies and elves is changed in a sophisticated age to an equal delight in the natural marvels of their prototypes, the insects.

Ye lovers of marvel and fairy lore,
Say not that the days of enchantment are o'er,

. . . .

There are streamlets yet where the river-sprite
With his Harlequin changes bewilders the sight;
There are castles yet of ivory and gold,
Hung with floral fabrics by sunshine unroll'd,
Within whose luxurious recesses recline
Fays of exquisite form, quaffing exquisite wine;
Some in gossamer veiled or ethereal dyes,
Which have only their match in the rainbow'd skies;
Some in richest and softest of velvets arrayed,
Or in mail that does shame to the armourer's trade.
These are haunting us ever for ill, or for good,
Through earth and through air, field, forest, and flood;
To transport our thoughts, as by magic spell,
From the sordid objects whereon they dwell,
To a land of the Marvellous dimly displayed,
Where light-winged Fancy, by wonder stayed,
Still delighteth to hover, and joyously say:
'Oh! my darling elves, ye're not chased away,
There's a region still where ye have a place—
The myterious world of the Insect race.'
—*Acheta Domestica, "The Moth Book—Holland."*

COLOR

In the distant past only the insect could supply that most adored color of the ancients—the beautiful scarlet which brightened the tapestries of Egyptian temples, adorned Phoenician beauties, and became the insignia of royalty denied to those of lowly birth. Though the chemist has long since surpassed the insect in his ability to transform drab cloth into fabrics glowing with color, he has never been able to rival the insect's own colors nor has the designer ever equalled the intricacy and beauty of his patterns. He obtains his most beautiful color effects when he abandons his own devices and faithfully attempts to reproduce the designs furnished by the insect. The butterfly costumes of the dazzlingly beautiful musical comedy, "Rio Rita," arouse the enthusiastic admiration of all who see them and commend the artistic taste of the designer who painstakingly followed the exquisite color patterns of the Papilionidae.

Of all the colorful insects that brighten his gardens and lawns, the poet shows the greatest fondness for those of golden hue. When he turns artist, he burnishes his canvas with the gold of grasshopper, beetle, butterfly and bee. With discriminating eye and skilled hand he pictures

> . . . the golden-cuirassed bee
>
> . . . .
>
> In the white lily's breezy tent.
>
> —*James Russell Lowell, "To the Dandelion."*

Or enlarging the canvas, he shows a garden,

> . . . fragrant everywhere;
> In its lily-bugles the gold bee sups,
> And butterflies flutter on winglets fair
> Round the tremulous buttercups.
>
> —*Munkittrick.*

Against the sunshine of a summer day, he paints a "Beetle panoplied in gems and gold,"[15] or a "gilded"[16] butterfly. In the eventide he shows in quiet, sweet beauty

> All the woods hushed—save for a dripping rose,
> All the woods dim—save where a glow-worm glows.
>
> —*Masefield, "The Watch in the Wood."*

Or with a few delicate strokes he depicts the soft radiance of the light of a

> . . . glow-worm golden
> In a dell of dew,
> Scattering unbeholden
> Its aereal hue
> Among the flowers and grass which screen it from view.
>
> —*Shelley, "To a Skylark."*

The poet constantly delights in the "circles of green radiance"[17] shed by the soft light of the glow-worm or firefly. Against a dark background De La Mare draws an enchanting

> . . . jasmine bower,
> Lit pale with flies of fire.
>
> —*"The Isle of Lone."*

and captures the allurement of a tropical night in his picture of

> . . . the isles where the pink coral and palm branches blow,
> And the fireflies turn night into day.
>
> —*"Andy Battle."*

Although the poet favors golden insects, he reproduces butterflies of all colors of the rainbow. Upon his canvas he throws "crimson wings,"[18] "vans, azure and green and gold,"[19] "purple plumes,"[20] the "wing'd violet,"[21] and and the "snow-white butterfly."[22]

Keats has recaptured the charm of an old mosaic in his

> . . . casement high and triple arch'd—
> All garlanded with carven imag'ries
> Of fruits, and flowers, and bunches of knot-grass,
> And diamonded with panes of quaint device,
> Innumerable of stains and splendid dyes,
> As are the tiger-moth's deep-damask'd wings;
>
> —*Keats, "St. Agnes."*

With a kindred love for a medley of color, Ina Coolbrith paints

> A jewelled moth; a butterfly, with rare
> And tender tints upon his downy wing
>
> . . . .
>
> Its petal-wings of broidered gossamer
> —winged bloom!—blossom-butterfly!
>
> —*"Mariposa Lily."*

Insects of brilliant hue enhance the beauty of a sunny landscape, those of neutral shades accentuate the dismal tone of a gloomy scene. Such are the "many a brown and dusky wing" flitting across a "moonless dun"[23] and a "great white moth" fading "miserably past."[24]

The poet seldoms introduces into his pictures of the unlovely any but insects of nondescript color. However, the colorful insects so numerous in cheerful scenes are caricatured by Montgomery as "insect legions, prank'd with gaudiest hues." Riley uncomplimentarily gives his butterflies "sallow-yellow" wings.

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[15] Wordsworth, "Indolence."

[16] Shakespeare, "Coriolanus," 1: 3.

[17] Wordsworth, "Evening Walk."

[18] Wordworth, "The Redbreast Chasing the Butterfly."

[19] Sir Edwin Arnold.

[20] Haworth, "Holland-Butterfly Book."

[21] Alfred Street.

[22] R. H. Horne, "Genius."

[23] Whittier.

[24] Henley.

The insect may lend beauty to any landscape or exquisite charm to the portrait of "The Tired Cupid,"

> A shimmering moth its pinions furls,
> Grey in the moonshine of his curls.
> —*De La Mare.*

Motion

Dancers

When the harmony of color and the poetry of motion unite in the graceful body of a colorful insect, the poet is entranced. What scintillating beauty in "the lightning flash of insect and of bird,"[25] in the dragonfly shooting by "like a flash of purple fire,"[26] in the sudden alighting of the "silken winged fly,"[27] in

> The beetle flashing in his minute mail
> Of green and golden scale;
> —*F. Thompson, "The 19th Century."*

The light of the firefly or glowworm, beautiful as it is in the stillness of a picture, is far more lovely in the changing radiance of the dance.

> Like winged stars the fire-flies flash and glance,
> —*Shelley, "Gisborne."*

or

> . . . flit, and swarm, and throng,
> Till all the mountain depths are spangled.
> —*Faust, 11.*

Living fireflies, enmeshed in gauze and worn as ornaments in the hair of natives of the Caribbean Islands, suggest that

> . . . the Pleiads, rising thro' the mellow shade,
> Glitter like a swarm of fireflies tangled in a silver braid.
> —*Tennyson, "Locksley Hall."*

A single glowworm "a moving radiance twinkles"[28] while many are "in the torch-dance circling."[29]

As if to let the spectators drink in their beauty

> The gold-barr'd butterflies to and fro
> And over the waterside wander'd and rove,
> As heedless and idle as clouds that rove
> And drift by the peaks of perpetual snow.
> —*J. Miller, "Isles of Amazons."*

In the dance of most delicate grace Endymion, beloved of a goddess, becomes dancing partner to a "golden butterfly," which pauses to refresh itself at

> The crystal spout-head;—with touch
> Most delicate, as though afraid to smutch
> Even with mealy gold the water clear.
> —*Keats, "Endymion."*

A bee leads a boy a merry dance.

> . . . the June bee
> Before the school-boy
> Invites the race;
> Stoops to an easy clover—
> Dips—evades—teases—deploys;
> Then to the royal clouds
> Lifts his light pinnace.
> —*Emily Dickinson, XXIX.*

Pan lies prone with

> . . . his face in the dazzle and glare
> Of the glad sunshine; while everywhere,
> Over, across, and around him blew
> Filmy dragon-flies hither and there,
> And little white butterflies, two and two,
> In eddies of odorous air.
> —*James W. Riley.*

The most colorful insects charm the poet by the beauty of their solo dances. The minute insects of nondescript, drab color seldom attract his attention unless they appear in a chorus where they become the personification of rhythmical grace.

> . . . there is dancing in yonder green bower,
> A swarm of young midges, they dance high and low.
> —*Owen Meredith (Lord Lytton.)*

For Robert Tannahil "The Midges Dance Aboon the Burn" in a fascinating manner. Francis Thompson enjoys watching the gnats as they "Maze, and vibrate, and tease the noontide hush."[30]

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[25] Tennyson, "Enoch Arden."
[26] "The Lover's Tale."
[27] Shelley, "Witch."
[28] Thomson, "Summer."
[29] Heine, "Donna Clara."

With a rare gift, the poet chooses backgrounds against which his insects can dance to best advantage. Whether he provides for them a stage emblazoned with all the theatrical devices for the spectacular or chooses instead a pastoral scene of simple charm, his performers dance with unsurpassed grace. Often the dance is interpretative rather than an interlude to interest the audience while the scenes are changing. Such is that of the

. . . snow-white butterfly
Dancing before the fitful gale
Far out at sea.
—*G. H. Horne, "Genius."*

Enchancing the weird atmosphere of "The Guerdon,"

A dragon-fly in narrowing circles neared,
And lit, secure, upon the dead man's beard,
Then spread its iris vans in quick dismay,
And into the blue summer sped away—
—*Aldrich, "The Guerdon."*

The horror of "The Massacre" is epitomized in the insects that avoid the terrible scene.

Never a whir of wing, no bee
Stirred o'er the shameful slain;
Nought but a thirsty wasp crept in,
Stooped, and came out again.
—*De La Mare.*

The repulsive finds a place on the poet's stage as effective as the gargoyles on the most beautiful cathedrals. Insects dance in such scenes as effectively as among the sweetest flowers.

. . . a hut bestrewn with skulls of beeves,
Round which the flies danced, where an Indian girl
Bleared at him from her eyes' ophthalmic eaves.
—*Masefield, "Daffodil Fields."*

Rivaling the beauty of the rapidly swirling dances are those motionless moments when the insect is poised, afloat as when

Deep in the sun-searched growth the dragon-fly
Hangs like a blue thread loosened from the sky;
—*D. Rossetti, "Silent Noon."*

or when "Amid the lilies floats the moth";[31] or when

. . . here and yonder a flaky butterfly
Was doubting in the air.
—*MacDonald.*

Acrobats

The insect acrobats of the air, performing daring feats, give an audience all the thrills of the sawdust ring. From a dizzy height the agile bee darts into a foxglove bell,[32] dives "into faint flowers," or "swings ower the white-clovery sod."[33] The show is over all too soon for Davies

When butterflies will make side-leaps,
As though escaped from Nature's hand
Ere perfect quite; and bees will stand
Upon their heads in fragrant deeps;
—*"Days Too Short."*

The spectator watches with rapt attention when "bees abashless play,[34] when they wrestle with cowslips,[35] when they row all day "upon a raft of air,"[36] and when with military precision

Baronial bees march, one by one,
In murmuring platoon;
—*E. Dickinson, LIX.*

With all the glamor of a medieval knight in combat, the bee bravely tilts away with many flowers.

Like trains of cars on tracks of plush
I hear the level bee;
A jar across the flowers goes,
Their velvet masonry.

Withstands until the sweet assault
Their chivalry consumes,

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[30] Francis Thompson, "Ode to the Setting Sun."

[31] De La Mare, "Lullaby."

[32] Wordsworth, "Borderers."

[33] MacDonald.

[34] E. Dickinson, CIV.

[35] Keats, "Ep. to Brother."

[36] E. Dickinson, CII.

While he, victorious, tilts away
To vanquish other blooms.

His feet are shod with gauze,
His helmet is of gold;
His breast, a single onyx
With chrysoprase, inlaid.
—*E. Dickinson, LXV.*

The daring feats of the insects are not always performed for their amusement, but sometimes become pressing necessities to evade the talons of a pursuing enemy. It is only by greater dexterity that the butterfly can escape the Redbreast,[37] an enemy of much greater size and strength. For the sport of Persian kings the butterflies were sacrificed in grim encounters with sparrows and starlings trained to capture them.[38] For the amusement of the populace, a cricket is sent out to meet in mortal combat another cricket armed with weapons as powerful as his own. The terrific struggle, which ends only when one of the contestants surrenders in death, holds the same fascination for the people of Japan as the cock fight for those of Mexico, or the bull fight for those of Spain.

Insects sometimes drown their troubles or celebrate their festivities in wine. Bees are not always the sober, industrious creatures they are reputed to be. The old adage of the straightness of the bee-line is completely reversed by the poet who has discovered that bees drink intemperately of the wine of many flowers. Would not the sages who have held up the bee as a pattern of exemplary conduct turn in their graves to see him reel "from bough to bough"?[39] sometimes getting so obstreperous that

. . . landlords turn the drunken bee
Out of the foxglove's door.
—*Emily Dickinson.*

Not only does the bee become "giddy with clover"[40] but drunk from the spicy wine of "carnations red." On the testimony of the poet the bee partakes intemperately of the wine of flowers; on the testimony of the distillers of the Blue Ridge Mountains, he imbibes too freely of the liquor of the corn. The distillers would be the last to criticize the morals of their customers, but they denounce the bee as an inveterate toper because, by his unseemly conduct, he inadvertently attracts the attention of revenue officers who follow his staggering path to their sheltered cove.[41] The poet now suspects that the bee is the reincarnated god of wine, Bacchus himself.

Listen to the tawny thief,
Hid beneath the waxen leaf,
Growling at his fairy host,
Bidding her with angry boast
Fill his cup with wine distilled
From the dew the dawn has spilled:
Stored away in golden casks
Is the precious draught he asks.

Who—who makes this micmic din
In this micmic meadow inn,
Wings in such a drowsy note,
Wears a golden-belted coat;
Loiters in the dainty room
Of this tavern of perfume;
Dares to linger at the cup
Till the yellow sun is up?

Bacchus 'tis, come back again
To the busy haunts of men;
Garlanded and gaily dressed,
Bands of gold about his breast;
Straying from his paradise,
Having pinions angel-wise,
'Tis the honey-bee, who goes
Reveling within a rose!
—*F. D. Sherman, "Bacchus."*

Bees are not the only inebriates of the insect world. Cicadas become "drunk with noonday dew"[42] and butterflies "go staggering"[43] through the air. Bees, in filching intoxicants, have but followed the example of flies that have always swarmed

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[37] Wordsworth, "The Redbreast Chasing the Butterfly."
[38] Burton, "On Melancholy."
[39] Oscar Wilde, "Her Voice."
[40] Jean Ingelow.
[41] "Greenville News."
[42] Shelley, "The Witch of Atlass," VIII.
[43] W. H. Davies, "Light."

. . . in vintage time,
About the wine-press where sweet must is poured,
—*Milton, "Paradise Regained," 4: 15.*

Though the bee win in acrobatic sports and though he pay deference to Bacchus, he does justify confidence in his industry. Gay, among a host of others, has seen him

With golden treasures load his little thighs,
And steer his distant journey through the skies,
—*Gay, "Rural Sports," Canto 1.*

The bee is not habitually a night club guest. At nightfall James Stephens often watches as

The bee
Speeds
Home!

Music

Whether the insect dance and play or work, he usually has a musical accompaniment for his activities. The efficiency expert, with the bombasity of a great discoverer, advocates music to increase the output of operatives in office, factory or mill. Long ago he might have learned from the example of the insect. However, man must overcome a difficulty which the insect has never had to surmount. He has the problem of timing the music to the actions of employees working at a different speed. The radio in the home is not always conducive to work, often becoming a distracting influence because of its erratic programs which may contain jazz tunes when slow painstaking work is attempted or a slow meditative melody when rapid work is undertaken. The music of the insect, on the other hand, is perfectly and inevitably synchronized with its movements. Flights of song and flights through the air are simultaneous, the rapidly vibrating wings accelerating the pace of the flyer and the tempo of the song or slowly waving wings retarding the rate of flight and prolonging the tones of the melody.

Many poets have gratified their curiosity by examining the insect's musical instruments. The ultra-modern Walt Whitman shares with the very ancient Meleager an interest in the mechanics of music. Whitman designates the wing of the katydid as a "chromatic reed."[44] Meleager pleads with the grasshopper: "—harp to me some tune of longing, striking thy vocal wings with thy dear feet." And he asks the cricket, that draws its leg like a violin bow over the chitinous wing surface, for music made "with serrated legs and swart skin."[45] Wordsworth explains that

The roving bee proclaims aloud
Her flight by vocal wings.
—*Wordsworth, "The Soaring."*

The human ear, as an imperfectly attuned radio, can receive but few of the insect melodies, and insect songs that to man seem only a monotone may be filled with lilting trills which fall unheeded on his coarse ears—ears which hear only the bass-drum notes of those high pitched melodies. How infinitely lovely must be the myriad unheard melodies of those aerial musicians whose very flight is song. What delicate overtures in that high treble when

The midge's wing beats to and fro
A thousand times ere one can utter 'O.'
—*Coventry Patmore, "The Cry at Midnight."*

Only the poetic mind that

. . . is ever startled by the leap
Of buds into ripe flowers; or by the flitting
Of divers moths, that aye their rest are quitting.
—*Keats, "I Stood Tiptoe upon a Little Hill."*

can faintly imagine the delicacy and grace of the musical accompaniment of the dance of the butterflies. Could the ecstatic notes of the song of the nuptial flight of the bees or the fireflies but reach the receptive ears of the poet, would he not be inspired to an answering epithalmion of unsurpassed beauty?

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[44] Walt Whitman, "Song of Myself."

[45] MacKail, "Meleager, Greek Anthology."

The fact that the music of some of the most graceful and beautiful insects is entirely inaudible, though regrettable, has some compensation for the poet. His fancy is free to compose in notes suitable for his ears accompaniments to their varied dances. He may answer for himself the intriguing question

Hast thou heard the butterflies
What they say betwixt their wings?
—*Tennyson, "Adeline."*

His response is sometimes a musical composition of impressionistic and interpretative type, comparable in the grace and beauty of its varied cadences to the dance it accompanies. However, when the poet attempts a literal translation of the insect's music, his composition is as lacking in spirit as the prosaic translation of a foreign poem.

Sometimes the poet, resorting to a little mechanical artifice, attempts a realistic reproduction of the music he hears. Such is "The Bees' Song," which begins with the stanza:

Thouzandz of thornz there be
On the Rozez where gozez
The Zebra of Zee;
  Sleek, striped, and hairy,
The steed of the Fairy
Princess of Zee.
—*De La Mare, "The Bees' Song."*

A somewhat similar feat is performed in "Chimes" with such couplets as—

Honey-flowers to the honeycomb
And the honey-bees from home.

A honey-comb and a honey-flower,
And the bee shall have his hour.
—*Dante Rossetti, "Chimes."*

In a less artificial and more suggestive stanza, Riley has recaptured something of the sound of the beetle's flight.

O'er folded blooms
On swirls of musk,
The beetle booms adown the glooms
And bumps along the dusk.
—*James Whitcomb Riley, "The Beetle."*

The music of the insect, which is produced by apparatus more nearly resembling that of a mechanical instrument than of the human voice, may usually be reproduced, except in the most impressionistic manner, with better effect in instrumental music than in poetry. Composers have vied with poets in beautifully expressing their impressions of the musical flight of insects in such interpretative compositions as "The Dragon-fly,"[46] "The Butterfly,"[47] and "The Fireflies."[48] The composer has surpassed the poet in the realistic reproduction of the music of "The Dance of the Mosquitoes," which was featured by Damrosch in a radio concert last winter. The most celebrated of all insect music is "The Flight of the Bumble-bee," in which Rimsky-Korsakow recaptures the actual sound of flight in a marvelously beautiful and realistic manner.

For long ages man has listened to the song of the insect. Until recently he did not know that the insect received enjoyment from his music. Not only man, but every creature, becomes a "slave of the sound" of music.[49] The sweet music which David played to soothe the troubled soul of Saul held a charm for all creatures that came within the circle of its magic spell.

Then the tune for which quails on the cornland
  will each leave his mate
To fly after the player; then, what makes the
  crickets elate
Till for boldness they fight one another;
—*Browning, "Saul."*

As if in a wood of enchantment, all creatures paused

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[46] Nevin.
[47] Greif.
[48] Several composers.
[49] Browning, "Abt Vogler."

Listening to my sweet pipings.
The wind in the reeds and the rushes,
  The bees on the bells of thyme,
The birds on the myrtle bushes,
  The cicale above in the lime,
And the lizards below in the grass,
Were as silent as ever old Tmolus was.
  Listening to my sweet pipings.
—*Shelley, "Hymn to Pan."*

The scientist corroborates the poet's fanciful picture by proofs of the insect's response to the music of orchestra or band, and tries to transform musicians into Pied Pipers to entice the injurious insects to follow them out of the country. He hopes to exact a price for his music far in excess of that charged by insect musicians that took a scant toll from his harvest.

The insect song is perennial. In his lovely little poem to "The Grasshopper and the Cricket," Keats has shown that the "poetry of earth is never dead," that when one insect song is silenced another begins.

Not only during all seasons of the year, but at all hours of the day, some insect song may be heard as an integral part of the great chorus of nature. Morning, noon and night, the tireless chorus continues.

. . . the light of morn, with hum of bees,
Stole through its verduous matting of fresh
  trees.
—*Keats, "Endymion."*

. . . 'Tis now the hour of deepest noon,
. . . while this multitude of flies
With tuneful hum is filling all the air;
—*Wordsworth, "Excursion."*

The grasshopper is praised as a

Green little vaulter, in the sunny grass,
  Catching your heart up at the feel of June,
  Sole noise that's heard amidst the lazy noon,
When ev'n the bees lag at the summoning brass.
—*Hunt, "Grasshopper and the Cricket."*

In the heat of a later day, even the grasshopper is silenced.

For now the noonday quiet holds the hill;
The grasshopper is silent in the grass;
—*Tennyson, "Oenone," 1: 26.*

In the evening different singers take up the refrain.

At eve the beetle boometh
  Athwart the thicket lone;
At noon the wild bee hummeth
  About the moss'd headstone;
At midnight the moon cometh,
  And looketh down alone.
—*Tennyson, "Claribel."*

At eve a dry cicala sung,
—*Tennyson, "Marianna in the South."*

The coming musk-rose, full of dewy wine,
The murmurous haunt of flies on summer eves.
—*Keats, "Ode to a Nightingale."*

The cricket sang,
And set the sun.
—*Emily Dickinson, CVI.*

The night-wind stirs the fern,
A night jar spins:
—*Masefield, "June Twilight."*

Just as the insect song blends in harmony with any chorus of nature, so, as music at the theater, it interprets the mood or heightens the effect of any drama. The poet has already shown how well insect music fits into any pastoral scene. He also demonstrates the fact that it belongs as well to any stage. He often chooses the versatile cricket's music which fits into many situations, augmenting loneliness or increasing mirth. The "squeak of the cricket"[50] adds to the loneliness of a secluded old woman, its shrill to the desolation of a ruin at twilight or the emptiness of a deserted house. However, Milton's gloomy stage is

Far from all resort of mirth
Save the cricket on the hearth.
—*Milton, "Il Penseroso."*

And at Shakespeare's theater

. . . crickets sing at the oven's mouth,
Aye the blither for their drouth.
—*Shakespeare, "Pericles," 111, Gower 7.*

The atmosphere of brooding tragedy is heightened when Macbeth, on the eve of murder, hears "the owl scream and the crickets cry."

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[50] De La Mare, "Alone."

Dormant fears of ghosts are all awakened in

Haunted old rooms: . . .
Where death-ticks knock and mouldering panels glow.
—*Masefield, "The Death Rooms."*

Isidore, awaiting the arrival of his mortal enemy, in the darkness of a cave hears the

. . . crash of water drops!
These dull abortive sounds that fret the silence
With puny thwartings and mock opposition!
So beats the death-watch to a sick man's ear.
—*Coleridge, "Remorse," IV: 1.*

In the tense stillness of the death chamber, the beating of the deathwatch comes presaging evil with a fearful impressiveness.

Waiting for your summons—
In the night, O, the night!
O, the deathwatch, beating!
—*Tennyson, "Forlorn."*

To some poets insect music is simply jazz—or worse—a mere noise. Henley, a patient in a hospital, petulantly complains:

I can hear a cistern leaking.
. . . .
Like the buzzing of an insect,
Still, irrational, persistent . . .
I must listen, listen, listen
In a passion of attention;
—*Henley, "Nocturne XXVII."*

Tennyson denies the mythological allegation that the grasshopper's song is the voice of the querulous and decrepit old Tithonus, who, at the request of the fair Eos, was granted eternal life, but through her negligence to request eternal youth also, was subject to the ravages of unending age.

No Tithon thou as poets feign
(Shame fall 'em, they are deaf and blind),
But an insect lithe and strong,
Bowing the seeded summer flowers,
Prove their falsehood and their quarrel,
Vaulting on thine airy feet,
Clap thy shielded sides and carol,
Carol clearly, chirrup sweet,
Thou art a mailed warrier in youth and strength complete.
—*Tennyson, "Tithonus."*

John Hall Wheelock calls the grasshopper's a "fairy song," but Goethe in an entirely different tone remarks:

. . . one of those long-legged grasshoppers,
Who flits and jumps about, and sings forever
The same old song i' the grass.
—*Goethe, "Faust," 1:49.*

Though the grasshopper has such a scant repertoire, his song does not grow monotonous to Shelley, who praises him for singing

Merrily—one joyous thing
In a world of sorrowing!
—*Shelley, "Invocation to Misery," V.*

Color, movement and song rival each other in their attraction for the poet. All these elements are seldom, if ever, found in their greatest perfection in any one insect. The butterfly, the most beautiful, is silent. The cricket, the cicada and the bee are not so colorful but are the most popular singers. The ancient Grecians, revering the butterfly as they did, wrote more poetry about musical insects. Crickets and katydids not only have an esthetic appeal but are of economic interest as well for the natives of South America, Africa, Italy and Portugal, who sell them in ornamental cages as songsters.[51]

Perhaps the music of the insect may never equal that of the bird as a source of inspiration for poetic song. The notes of the soaring skylark, striking upon the responsive strings of Shelley's heart, awoke an echoing melody of matchless beauty. However, the song of the insect blends with the song of the poet in many lovely rhythms. Many poets acknowledge their indebtedness to the insect musicians. Wordsworth said

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[51] Metcalf and Flint.

. . . my leisure draws
A not infrequent pastime from the hum
Of bees—
—*Wordsworth, "Excursion," 6: 1169.*

And Emily Dickinson charmingly confesses

The murmur of a bee
A witchcraft yieldeth me.

Martin Doule, in his lament for the disillusions of restored sight, recalled with regret the loss of the privilege of "hearing the birds and the bees humming in every weed of the ditch."[52]

Small wonder that Yeats, in dreaming of an ideal home, longed to have

. . . a hive for the honey bee
And live alone in the bee-loud glade.
—*Yeats, "The Lake Isle of Innisfree."*

Nor is it surprising that the poet thinks of Eden as a garden where

Bees, in the cherry-blossom snow,
Rehearsed the earliest honey-humming tune.
—*Eden, "Best Poems of 1927."*

SLEEP

Though in infancy the poet is lulled to sleep by the voice of his mother softly crooning

Baby bye,
Here's a fly,
Let us watch him, you and I,
—*T. Tilton, "Baby Bye."*

in manhood he is soothed into slumber by the lullaby of the bee. In the absence of the bee he sometimes behaves as a recalcitrant child, resenting the droning melodies of other insects. Of course, these insects, as impatient nurses, sometimes administer stinging punishments and then increase the tempo and volume of their songs to drown out the cries of the wailing infant. Wordsworth, usually so calm and poised, displays the temperament of a grand opera star in matters pertaining to sleep, which he calls

A Fly, that up and down himself doth shove
Upon a fretful rivulet, now above,
Now on the water vexed with mockery.
—*Wordsworth, "O Gentle."*

However, he enlists the sympathy of all who hear him fretfully complaining that he

. . . could not sleep, tormented by the stings
Of insects, which with noise like that of noon
Filled all the woods:
—*Wordsworth, "Prelude," 6: 712.*

Though he closes his ears to all sounds, and, as a kind of charm to induce sleep, thinks of bees, as one counts sheep, he is still wakeful.

A flock of sheep that leisurely pass by,
One after one; the sound of rain, and bees
Murmuring; the fall of rivers, winds and seas,
Smooth field, white sheets of water, and pure sky;
I have thought of all by turns, and yet do lie
Sleepless!
—*Wordsworth, "A Flock."*

Keats, Shelley, Byron, Coleridge and Tennyson, when weary of singing their own sweet songs, long for the bee to take up the gentle refrain and soothe them to sleep as she sings to the accompaniment of a gently murmuring stream.

Hide me from Day's garish eye,
While the bee with honeyed thigh,
That at her flowery work doth sing,

And the waters murmuring,
With such consort as they keep,
Entice the dew-feathered Sleep.
—*Milton, "Il Penseroso."*

The lullaby of the bee, charming melody that it is, lacks something of the poignant beauty of that heard by Keats when he watches as

. . . the night's sleepy eye
Closes up, and forgets all its Lethean care,
Charm'd to death by the drone of the humming May-fly.
—*Keats, "Hush, Hush, Tread Softly."*

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[52] Synge, "The Well of the Saints."

To the lullaby of the bee, man slips into sweet repose; to the dirge of the beetle, he sinks into sleep eternal. Keats, in his "Ode on Melancholy," says

> Nor let the beetle, or the death-moth be
> Your mournful Psyche.

In Gray's "Elegy in a Country Churchyard"

> . . . all the air a solemn stillness holds,
> Save where the beetle wheels his droning flight.

When the raven dies, he, too, wants to go to his last rest to the strains of the beetle's funereal music.

> Summon the haunted beetle,
> From twilight bud and bloom,
> To drone a gloomy dirge for me
> At dusk above my tomb.
> Beseech ye too the glowworm
> To rear her cloudy flame.
> —*De La Mare, "The Raven's Tomb."*

Both gnats and crickets join in a dirge to the dying year:

> Then in a wailful choir the small gnats mourn
> Among the river shallows, borne aloft
> Or sinking as the light wind lives or dies;
> And full-grown lambs loud bleat from hilly bourn;
> Hedge-crickets sing;
> —*Keats, "To Autumn."*

The poet as musician transposes the song of the insect to harmonize with any melody he sings, as artist he reproduces its color to blend with any hues on his canvas, as sculptor he models its form into images of thought of greater beauty and variety than the most superb statues ever molded from

> The waxen labour of Hymettus' bees,
> By plastic fingers wrought, to various shape
> And use by use is fashioned.
> —*Ovid, Greek Anthology.*

THE LOVER

Poetic fancy flies with honey-hunting insects and rests in charming revery upon the flowers. The courtship of insects and flowers is a delicate and beautiful theme.

> . . . birds, and butterflies, and flowers,
> Make all one band of paramours.
> —*Wordsworth, "Green Linnet."*

The flower, enamored of the butterfly, pleads that he "wanton not from spot to spot"[53] but remain her constant lover. Love-lorn flowers dream "of moths that drink them under the moon."[54] Cupid reverses his arrow and the butterfly becomes the wooer.

> With the rose the butterfly's deep in love,
> A thousand times hovering round;
> But round himself, all tender like gold,
> The sun's sweet ray is hovering round.
> —*Heine, "New Spring Song," 7.*

> Auto-da-fé and judgment
> Are nothing to the bee;
> His separation from his rose
> To him seems misery.
> —*E. Dickinson, LXXI.*

Insects, so charming in their own courtships, fly to the assistance of the poet in his affairs of the heart. The lover often chooses insects to convey messages to his beloved. Meleager asks a mosquito to fly swiftly to Zenophila and whisper into her ear his words of invitation, and promises rich rewards if he entice her to come.[55] However, the lover seldom entrusts his all-important errand to a less trustworthy messenger than the bee. Herrick, with an extravagance not only excusable, but charming, in an infatuated suitor, sends the bee as a messenger but threatens to make him both sexton and mourner if his mistress reject his gift.

> Fly to my Mistresse, pretty pilfring Bee,
> And say, thou bring'st this Hony-bag from me:
> When on her lip, thou hast thy sweet dew plac't,
> Mark, if her tongue, but sloly, steale a taste.
> If so, we live; if not, with mournfull humme,
> Tole forth my death; next, to my buryall come.
> —*Herrick, "The Present."*

[53] Hugo, "Flower to Butterfly."
[54] H. Brooke, "Great Lover."
[55] Patou, "The Greek Anthology."

Man, when a fickle lover, darting from paramour to paramour, finds an exact counterpart in "The Butterfly Beau,"[56] flitting from flower to flower, tasting all their sweets and being true to none. Yet a Scottish maid, in an oath of constancy, swears

While bees delight in opening flowers;
While corn grows green in simmer showers,
I'll love my gallant weaver.
—*Burns, "The Gallant Weaver."*

The rejected lover of Amaryllis modestly prays

Look on me kindly, and some pity show,
Or give me leave at least to look on you.
Some god transform me by his heavenly power,
E'en to a bee to buzz within your bower,
The winding ivy-chaplet to invade,
The folded fern, that your fair forehead shade.
—*Theocritus-Dryden, "Amaryllis."*

Romeo, banished, envies the flies their intimacy with Juliet.

. . . more courtship lives
In carrion flies than Romeo: they may seize
On the white wonder of dear Juliet's hand,
And steal immortal blessing from her lips;
Who, even in pure and vestal modesty,
Still blush, as thinking their own kisses sin;
But Romeo may not; he is banished,
This may flies do, when I from this must fly.
—*Shakespeare, "Romeo and Juliet," III: 3*

What lady could refuse a plaintive request for a kiss when her lover willingly metamorphoses himself into a bee and flatteringly implies that her lips are a rose?

But, Delia, on thy balmy lips
Let me, no vagrant insect, rove;
O let me steal one liquid kiss,
For, oh! my soul is parched with love!
—*Burns, "Delia."*

With little coaxing Philly grants her lover a kiss. He leaves no doubt as to his appreciation when he says:

The bee that through the sunny hour
Sips nectar in the opening flower,
Compared wi' my delight is poor,
Upon the lips o' Philly.
—*Burns, "Philly and Willy."*

Donne presents a circuitous argument for undue liberties, contending that his blood and that of the lady to whom he is paying court are mingled in the flea which has bitten them both. The lady indignantly kills the flea. Then Donne, not to be outdone, turns this episode to his account, remarking

Yet thou triumph'st, and say'st that thou
Find'st not thyself nor me the weaker now.
'Tis true; then learn how false fears be;
Just so much honour, when thou yield'st to me,
Will waste, as this flea's death took life from thee.
—*Donne, "The Flea."*

In striking contrast to Donne, Shelley gives expression to a beautiful, etherealized love.

I can give not what men call love,
But wilt thou accept not
The worship the heart lifts above
And the Heavens reject not,
The desire of the moth for the star,
Of the night for the morrow,
The devotion to something afar
From the sphere of our sorrow?
—*Shelley, "One Word."*

Lovers of to-day, as those of long ago, choose from the bee's vintage liquid terms of endearment. From the pages of Chaucer the lips of a lover frame again the words

. . . Honycomb, sweete Alisoun,
My faire bryd, my sweete cynamone.
—*Chaucer, "The Miller's Tale."*

The sweetness of a "honied" courtship is but changed in marriage to

The lusty lyf, the vertuous quyete,
That is in mariage hony sweete;
—*Chaucer, "The Merchant's Tale."*

THE POET

Shelley, though denounced by moralists as a worm, has unravelled the threads of the coarse mantle of scorn thrown about him and rewoven them into a fabric, sheer and lovely, matching in texture the web of the most skilled insect artisan.

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[56] T. H. Bayley, "Butterfly Beau."

> The silk-worm in the dark green mulberry leaves
> His winding sheet and cradle ever weaves;
> So I, a thing whom moralists call worm,
> Sit spinning still round this decaying form,
> From the fine threads of rare and subtle thought—
> No net of words in garish colours wrought
> To catch the idle buzzers of the day—
> But a soft cell, where when that fades away,
> Memory may clothe in wings my living name
> And feed it with the asphodels of fame.
> —*Shelley, "Letter to Marie Gisborne."*

Though the poet satirize some of his fellow artists and their style by comparing them to certain insects, he shows a fond predilection for picturing himself and the poets he admires as other insects. Perhaps his partiality for bees may be traced to his miraculous deliverance from starvation by their intervention.

> And, O Theocritus, so far have some
> Prevailed among the powers of heaven and earth,
> By their endowments, good or great, that they
> Have had, as thou reportest miracles
> Wrought for them in old time: yea, not unmoved,
> I hear thee tell how bees with honey fed
> Divine Comates, by his impious lord
> Within a chest imprisoned; how they came
> Laden from blooming grove or flowery field,
> And fed him there, alive, month after month,
> Because the goatherd, blessed man! had lips
> Wet with the Muses' nectar.
> —*Wordsworth, "Prelude," II: 443.*

The poet, his methods and his works are complimented by insect analogies. When gaining impressions that were later to be translated into his poetry, Wordsworth, looking out over a wide expanse of water, was

> . . . gathering as it seemed,
> Through every hair-breadth in that field of light,
> New pleasure like a bee among the flowers.
> —*Wordsworth, "Prelude," I: 580.*

In highest tribute to Pindar, before whose melody all other lutes were mute, Antipater praised:

> Not vainly did the swarm of brown bees drip
> Their wax-bound honey on your infant lip.

Menander is similarly praised.

"The bees themselves on thy lips honey dropped."[57] "Honer with the honey mouth"[58] and Shakespeare smiling from the "honeyed corner at his lips,"[59] have given to the world a rich legacy of words that "been honeycombes, for they geven swetnesse to the soule and hoolsomnesse to the body."[60]

What more beautiful illustration of the inspiration of the poet than that of the nightingale, most superb of all singers, feeding upon the glowworm.

> For as nightingales do upon glow-worms feed,
> So poets live upon the living light.
> —*Bailey, "Festus, Sc. Home."*

Listening in rapt attention to the poet's "honeyed" words, people

> . . . on his eloquent accents fed and hung
> Like bees on mountain-flowers:
> —*Shelley, "Revolt of Islam."*

Or, as Lucretius says in praise of Epicurus,

> As the bees in the flower-grown meadows take the
> sweets from all the flowers, so we also satiate
> ourselves with your golden sayings, golden indeed,
> and ever worthy of endless life.
> —*Lucretius, "De Res. Nat.," 3: 11.*

The sonnet has been lauded by many poets, but perhaps nowhere with happier effect than by Wordsworth when he says:

> The Sonnet glittered a gay myrtle leaf
> Amid the cypress with which Dante crowned
> His visionary brow; a glow-worm lamp,
> It cheered mild Spenser, called from Faery-land
> To struggle through dark ways;
> —*Wordsworth, "Scorn Not."*

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[57] Anon., On Menander, Greek Anthology, Collins.

[58] Chaucer, "Boethius," Bk. 5, N 2.

[59] Meredith, "Spirit of Shakespeare."

[60] Chaucer, "Melibeus."

(*To be concluded in the next number*)

SCIENCE SERVICE RADIO TALKS

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THE MAGNETISM OF THE EARTH

By J. A. FLEMING

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THE earth is a great spherical magnet. Unlike the force of gravitation, the earth's magnetism is a phenomenon which we can not immediately recognize through our physical senses. An unexpected fall tells you forcibly of the existence of gravitation but you never notice any effect from the earth's magnetic force although it is as real as that of gravity.

The discovery of the lodestone or natural magnetic rock with its mysterious power of attracting objects made of iron was the first step in the study of the earth's magnetism. This magnetic property of the lodestone—the so-called leading stone of the Scandinavians, the loving-stone of the French—was known to the Greeks over six hundred years before Christ. As is the case for so many discoveries, the Chinese are credited with an earlier knowledge of the directive property of the lodestone. Chinese legends 2,600 years before the Christian Era tell of the south-pointing war-chariot. In Japan south-pointing carts were known in the seventh century. Europeans did not become acquainted with the properties of the lodestone until about four hundred years later.

In experimenting with lodestone it was found that when mounted on a block of wood and floated in water it always indicated the north-south direction. This paved the way for the development of the magnetic compass by European navigators beginning in the eleventh century. The voyage of Columbus, in 1492, showed that the compass direction changes from place to place. In 1576, it was discovered that one end of a compass needle supported on a horizontal axle would dip below the horizon. In 1600, William Gilbert concluded from the behavior of the compass needle in different parts of the earth that the earth itself acts like a great spherical magnet. His discovery thus preceded that of universal gravitation by Newton. The earth is a feeble magnet, for it is not highly magnetized. It is possible to magnetize our modern hard steels ten thousand times as much as the earth. Even at that, since the earth is large its total magnetism is equivalent in effect to that of eight hundred quintillion one-pound magnets of our best magnet steel could they be placed at the center of the earth.

The earth is not uniformly magnetized and the principal magnetic poles, those places where the inclination is 90°, are distant 1,200 miles or more from its geographic poles. The north magnetic pole, the region of which was first visited in 1831 by Ross and again in 1903 by Amundsen, is on Boothia Peninsula in northern Canada approximately in latitude 70° north and in longitude 96° west. The south magnetic pole, in South Victoria Land, has not yet been surveyed; it is approximately in latitude 73° south and in longitude 156° east. Thus the magnetic poles are not diametrically opposite each other, the line joining them passing some 750 miles away from the center of the earth.

The earth's magnetism extends its influence or magnetic field far out into space. The field at a distance of 4,000 miles above the earth's surface is still one eighth as great as at the surface. One may picture the field as made of innumerable lines of magnetic force or action closely packed together. Near the equator these lines of force are parallel to the earth's surface, but as they approach the magnetic poles they bend and converge. Minute electrified particles are coming continually from the sun. Once within the earth's magnetic field, these particles or corpuscles travel in paths around the lines of magnetic force. They get deeper down in our atmosphere in the polar regions, where the magnetic-force lines are steepest. When the electrified particles pass through the atmosphere, they are made to glow by the resistance encountered. These glowing particles cause the brilliant polar-light displays we sometimes see in the northern sky and which are also seen in the southern sky by people living in the southern hemisphere. From simultaneous photographs of aurora it has been found that polar-light beams generally do not come closer to the earth's surface than about 60 miles and have been observed to heights of 300 miles and more.

We investigate the earth's magnetism by studying its field or its effects outside the earth. There are many regions where local magnetic disturbances, for example, those caused by magnetic ore deposits, give rise to local poles and to further irregularities in the earth's general magnetic field. Therefore, magnetic observations must be made at many places to determine with reasonable correctness the distribution of the earth's magnetism.

There are also progressive changes in the earth's magnetic elements. These vary from place to place and for the same place from time to time. Such progressive changes or secular variations were first noted by Gellibrand in 1634. The importance in any practical use of the magnetic compass of these changes may be realized from observations at London made during the past 350 years. There the magnetic needle pointed 11° east of north in 1580, 24° west of north in 1812, and since then has again shifted eastward and now points only about 13° west of north. These results indicate that there is a complete cycle of change in the direction of the compass needle in about 500 years. Centuries more of observations will be needed to verify these indications.

The complexity of the earth's magnetism is further shown by other perplexing periodic and irregular changes or variations. There is a daily variation which varies with time, position on the earth, season, and sun-spot frequency and other cosmical relations. There is also an annual inequality.

More fascinating than these periodic variations are the irregular ones of various types. These frequently occur almost simultaneously over the whole globe, their violence increasing generally as the place of observation is nearer a magnetic pole. These magnetic storms are in general simultaneous with displays of the polar lights. They are associated with the number and size of sun-spots and increase with increased sun-spot activity. They also are frequently accompanied by pronounced disturbances of the natural electric currents within the earth, that is, earth-currents. If severe, they often prevent telegraphic and radio communication, thus taking an important place in everyday practical affairs. They bear no relation to stormy weather conditions. In the stormiest weather there may be no magnetic storms while during the finest weather there may be a severe magnetic storm in progress.

Since the magnetic state of the earth is so complex and subject to so many influencing factors, observations must be obtained at many points. This is done by systematic magnetic surveys and by operating magnetic observatories. Such magnetic surveys and observatories are maintained by a majority of the nations of the world. In the United States this work is in charge of the Coast and Geodetic Survey of the Department of Commerce. In addition to its field observations, the survey operates five magnetic observatories, one in Maryland, one in Arizona, one in the Hawaiian Islands, one in Alaska, and one in Porto Rico. Since 1904 the Carnegie Institution of Washington, D. C., has maintained a department of terrestrial magnetism for the study of the earth's magnetism and electricity and to complete the earth's magnetic survey by observations on land in those countries where there are no systematic surveys and over the oceans. For the observations at sea that institution designed and constructed the non-magnetic ship *Carnegie*. This vessel was unfortunately destroyed in November, 1929, by fire in Western Samoa. From 1909 she cruised over 300,000 nautical miles in all oceans and had completed the general magnetic distribution survey of the oceans. Magnetic-variation charts for the ocean regions, so important to the safety of shipping, have for many years utilized to a great extent the observations made on the *Carnegie*. This institution also operates two magnetic and electric observatories in the southern hemisphere where, of the world total of about seventy, there are only eleven observatories. One of these is some 120 miles north of Perth at Watheroo, Western Australia, and the other is at Huancayo, Peru, about 120 miles east of Lima in the high Andes at an elevation above sea of two miles.

Recent analyses of available magnetic data between latitude 60° north and 60° south by the Carnegie Institution of Washington show that over nine tenths of the total magnetic field arises from magnetic or electric systems within the earth and the remaining part from similar systems outside the earth. Additional observations to improve these analyses are needed in polar regions, where the transient magnetic and electric variations and storms are extremely emphasized because of the proximity of the earth's magnetic poles. Thus the additional reliable observations in these regions proposed by the Wilkins-Ellsworth Trans-Arctic Submarine Expedition for 1931 and by the many polar stations proposed in the program of the International Polar Year Commission for 1932–33 are of exceptional importance.

Observations during the last century at stations in Europe and in the United States have revealed the close relation between sun-spot activity and disturbances of the earth's magnetism. Another interesting feature of the earth's magnetic activity is that as the earth revolves about the sun the maximum changes in magnetic, earth-current, and polar-light activity occur during the equinoctial months of March and September, and the minimum during the solstitial months of June and December.

We have not yet learned definitely the cause of the variation in the earth's magnetic field. Despite this, magnetic observations have added materially to our knowledge of the earth's interior, particularly to some of the geological features of the earth's crust. Thus the secular variation suggests changes within the crust, indicating an interior more mobile than the exterior layers. These studies give us additional information regarding the high atmosphere above the earth and, in particular, regarding the Kennelly-Heaviside layer. Observations of fluctuations in height of this layer show its fundamental importance in terrestrial magnetism and in radio transmission.

The penetrating radiation or cosmic

rays from space may be the connecting link to tie together in a satisfactory theory the present indications of the sun and of the variable electric currents in our atmosphere and within our globe as the ultimate causes of the earth's magnetism and its variations. Therefore, laboratory experiments have been conducted for some years by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington in the study of the structure of the atom and its magnetic properties through the artificial production of high-voltage radiations. Another connecting link may be in possible modifications in the physical properties in the higher atmosphere from those in lower altitudes of which we know. Researches in this connection await development of rockets capable of reaching heights from 25 to 50 miles or even more. Recent tests indicate early realization of technique to accomplish this.

HUNGER

By Dr. A. J. CARLSON

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MODERN research on man and animals permits us to state the following facts concerning the nature and control of hunger. Whether we use the word hunger in its widest or most limited sense, it describes one of the most common and most important experiences of living organisms. Hunger pangs have been felt by every individual of the human race and have unquestionably determined many of the actions of their lives. Whether other animals besides human beings feel hunger pangs is still a matter of conjecture, but, if we employ the word hunger in its quite legitimate sense as the total of conditions determining the ingestion of food, we shall not exaggerate in saying that hunger is the most potent single influence in life. At times the sex urge is more of a drive to activity, but the sex stimulus is dormant in childhood and fails with advance in years, while hunger is potent throughout life.

Despite the commonness of the hunger sensation(to return to the more limited definition of the word), our knowledge of its real nature is far from final. It is not even easy to describe our subjective experience of it. If we call it emptiness or hollowness, we are not really describing what we feel. Instead we are expressing our knowledge that our stomach is empty of food when we feel that uncomfortable sensation in our midregion. The hunger sensation can be correctly described as painful epigastric tension and pressure, but this, too, is unsatisfactory.

A charactertistic element in the hunger complex is its intermittency, its occurrence in sharply defined periods. This is true even though the stomach is continuously empty and the physical activity of the individual is uninterrupted. It seems to hold also for other mammals and for birds. In the lower animals, to judge by the motion of the empty stomach, it is nearly continuous.

Although in normal persons the hunger sensation must become exceptionally strong to be markedly painful, the epigastric sensation of varying degrees of pain is the indispensable subjective element. Frequently, however, there is a feeling of general lassitude or weakness. Sometimes headache, nausea, nervous irritability, restlessness and even fainting may appear as a part of the hunger complex. Strictly speaking, a certain degree of nervous excitability is a necessary effect of hunger of even moderate intensity, but in normal persons with stable nervous organizations strong hunger is seldom accompanied by any of these obvious manifestations of nervousness. In some individuals, on the other hand, the accessory phenomena may be so marked as to crowd out of consciousness the central factor of hunger, the gastric hunger pangs.

When we feel hungry, why do we eat? The obvious reply is that we know that eating will relieve us of the pangs. But how did we learn? A new-born infant can not know what effect the ingestion of food will have on the hunger sensation, because he has never had food in his stomach. What induces the new-born animal to take food? Is it a matter of inherited reflexes (instinct)? The feeding reflexes are present at birth, and so are the defensive ones which reject unpalatable and injurious substances. We have seen that hunger increases excitability. Hunger then probably causes the infant to put more things into his mouth, to be either swallowed or rejected. Palatable materials in the mouth and any materials in the stomach stop the hunger pangs, and the infant animal learns by the trial-and-error method that by eating discomfort is changed to comfort.

The exact cause of the hunger sensation is still a matter of dispute, although, to my mind, the theory of peripheral origin has been conclusively proved but not completely worked out. The peripheral theory holds that the hunger sensation is inaugurated in sensory nerve endings, mainly in the upper part of the digestive tract (stomach, lower esophagus and small intestines). Some investigators hold that the origin of hunger is in a hypothetical hunger center of the brain, which is stimulated by food deficiencies in the blood or brain tissues. There is experimental evidence that hunger may, in fact, often does, begin even before the stomach is completely empty and long before there could be any food deficiency in the blood or tissue. It has further been shown by experiment that hunger pangs coincide almost identically, both in time and intensity, with certain strong rhythmic contractions of the stomach, which begin as the stomach is emptying and continue in intermittent groups until inhibited by the ingestion of some material or by some abnormal condition, such as strong emotion or the action of drugs. These contractions have been termed hunger contractions. I regard as conclusive proof that hunger pangs are initiated by these contractions (through some sensory mechanism which has not yet been determined) the fact that an artificially stimulated hunger contraction in an otherwise quiescent stomach will invariably give rise to a hunger pang.

The existence of intermittent hunger contractions, as well as the several other types of movements of the stomach, has been ascertained by several methods of objective observation on the stomachs of normal and abnormal man and animals. The stomach may be observed either directly through a fistula, by means of the x-ray and barium in the stomach, or with the aid of a balloon, which, when inflated in the stomach and connected by a rubber tube to a recording instrument, will yield a continuous record of its movements.

In the normal human being a single hunger contraction endures on an average of 30 seconds. They come in periods of from 30 to 45 minutes, which are separated by periods of repose from 30 to 150 minutes long. The individual contractions in each period are separated by periods of quiescence at first but are practically continuous at the end. In infants the periods of quiescence are shorter, gradually increasing to reach their maximum in senile old age. This is what we would expect, knowing that body metabolism (rate of food combustion) decreases gradually from youth to old age. The stomach muscles do not seem to share completely this decline, since starvation, even in old age, will give rise to strong contractions.

The stomach is supplied with various sensory and motor nerves from the central nervous system. The function of these nerves seems to be, in general, one of modification, similar to that of the nerves to the heart in the regulation of the heart rhythm. Even when all the central nerve connections are severed, the stomach exhibits typical hunger contractions. In sleep, hunger contractions are more vigorous and regular than in the waking state. During sleep there is a general decrease in activity of the central nervous system, evidenced by decreased activity in all the other neuromuscular mechanisms, such as skeletal muscles, blood vessels and urinary bladder. One might expect to find the same condition in the empty stomach. The phenomena of increased activity indicates that the tonus mechanism of the stomach occupies a unique place in the organism.

Emotional states of the higher nerve centers, such as anger, fear and joy, inhibit hunger contractions. Intellectual states, such as attention, reading and reasoning, have no distinct effect on the course of the hunger period. Contrary to popular belief, the sight or smell of food does not intensify hunger contractions; if there is any effect it is in the other direction. In this case the hunger pangs are probably reinforced through some central mechanism. The basis for the view that hunger "cravings" can be changed at will is probably to be found in the fact that mild hunger contractions do not enter consciousness if the attention of the individual is diverted in any way. The attention to hunger is usually aroused, consciously or unconsciously, about the time the individual is accustomed to eat. Therefore, if he changes that time, he can to a certain extent change his experience of hunger pangs.

One of the chemical factors in the blood that has been shown to influence gastric hunger contractions and the conscious hunger sensations is the sugar. When the blood sugar is markedly decreased hunger is increased, and *vice versa*. This is probably one of the reasons we can so quickly appease hunger with candies or sugar, as this type of food enters the blood quickly.

Hunger is increased in such diseases as diabetes. It is decreased in fevers and in most disorders of the digestive system. Hunger is not directly influenced or increased by tonics. Appetite seems to be merely the memory of past experience (sight, taste, smell) with food. Appetite is therefore a pleasant subjective process or sensation, while hunger is built into the very framework of the animal machine and is not essentially modified by the experiences of the individual, except as this induces strong emotional states.

The hunger pangs, due to the strong contractions of the empty stomach, continue throughout fasting almost to death. The view that hunger disappears after a few days' fasting is an error. But disturbances in our conscious life can overshadow our hunger feeling or even change it to nausea. Thus we see that the working of the hunger mechanism requires a normal stomach with its sensory nerves, and also a normal or nearly normal brain. In the normal person, the hunger felt, even in prolonged starvation, is uncomfortable, but not actually or acutely painful. There is no heroism in "Hunger strikes."

AT THE HEAD OF THE CACAPON

By Dr. J. G. NEEDHAM
CORNELL UNIVERSITY
and P. D. STRAUSBAUGH
WEST VIRGINIA UNIVERSITY

IN Hardy County, West Virginia, a small clear river comes tumbling down between two of the parallel ridges of the Allegheny Mountains, and at the foot of Sandy Ridge, which lies across its further course, it descends into the earth. It goes down through a number of gravel-filled holes in its limestone bed, gurgling a bit noisily in some of them, and with a sound of falling water in the distance underground. Thus it disappears from view, to reappear some three miles distant on the other side of the ridge, like a great upwelling spring. It gets another name in the process. Before it disappears underground it is known as Lost River; after its reappearance it is the Cacapon.[1]

This stream is well enough known[2] to geologists, who have taken much interest in it. Its course is fairly well shown in the Wardensville topographic quadrangle of the U. S. Geological Survey. It should be better known to biologists, especially the portion of the head of the Cacapon; for here is a very unique environment that shelters wonderfully interesting flora and fauna.

It is our purpose in these pages to call attention to some of the things of interest that were found at the head of the Cacapon by the members of the West Virginia University Biological Expedition during the week of their encampment near Wardensville, in August, 1930.

The river emerges from its long course underground well filtered. Its waters are clear and sparkling. They run glistening down the riffles, and settle in pools of wonderful transparency. Fishes swimming in the pools and water plants swaying in the current are seen almost as clearly as through air; and even the fine silken nets of the caddisworm, Hydropsyche, that elsewhere are commonly hidden under a load of adherent silk, here stand out clearly showing the meshwork of their white threads. The waters are remarkably clear.

The steep mountain sides on either bank of this winding stream are covered with forest, much of which is still of primeval aspect. Azaleas, laurels and rhododendrons peep out from under the edges, and where the foot of the slope meets the stream there are great banks of royal fern. Elsewhere willows and alders crowd the streamside, with tall wands of meadow-rue and Jo-pye-weed and tufts of bulrush and flaming spikes of cardinal flowers rising here and there among the rocks. The gradient is moderate for a mountain stream, but sufficient to maintain long stretches of rocky rapids and a few low waterfalls, with pools of gentle onflow lying between. There are long stretches of uptilted rock ledges over which the water breaks in shallow riffles and these ledges are thickly covered with a dense inch-high vegetation consisting mainly of the curious leafless waterweed, Podo-

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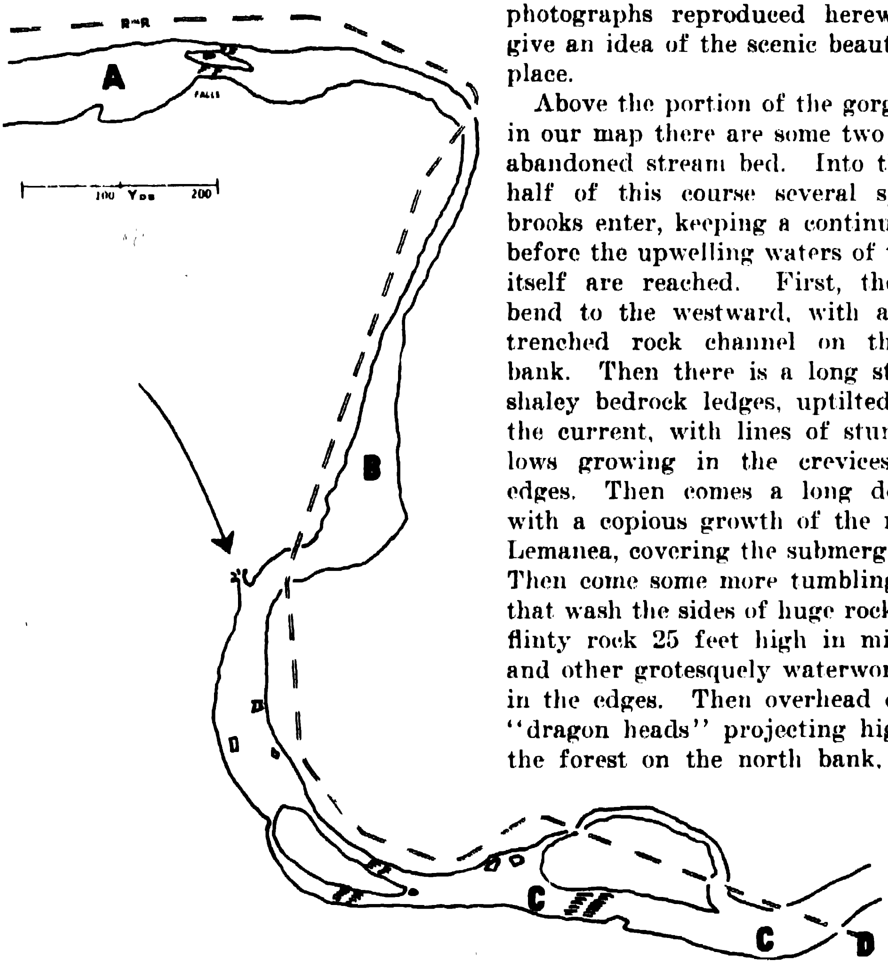
[1] Indian name "Kaka pon-de-pe" (according to Conley's Encyclopedia of W. Va.) signifies "River of Medicine Waters" and was doubtless suggested by the numerous springs of therapeutic value along its course.

[2] George Washington visited it on horseback (as recorded in his diary) on April 10, 1747, in the course of a thirteen months' surveying trip made when he was 15 years old.



SKETCH MAP OF THE HEAD OF CACAPON RIVER.
ARROW INDICATES WHERE THE RIVER MERGES FROM UNDER THE MOUNTAIN; ABOVE IT LIES THE FLOOD-WATER CHANNEL, IN WHICH, IN THE PORTION HERE SHOWN, WATER IS KEPT FLOWING BY SPRING-FED TRIBUTARY BROOKS. *A*, ISOETES POOL; *B*, LONG POOL; *CC*, BASS POOLS, *D*, THE FOOT OF THE GORGE AND ENTRANCE FROM THE WARDENSVILLE (EASTERN) SIDE; *RR*, LOG RAILROAD.
Prepared by A. F. Rohrbough, N. B. Green, R. K. Brown and R. E. Douglas.

stemum and mosses. In the clear pools float cumulous masses of algae. The bottom of the pools is formed of broad flat rock, with sparse swaying tufts of waterweeds growing in the crevices. There is but little place for the lodgment of sand and gravel.

Herewith we present a sketch map of a portion of the channel near the head of the Cacapon. It shows the succession of pools and waterfalls, and the photographs reproduced herewith will give an idea of the scenic beauty of the place.

Above the portion of the gorge shown in our map there are some two miles of abandoned stream bed. Into the lower half of this course several springfed brooks enter, keeping a continuous flow before the upwelling waters of the river itself are reached. First, there is a bend to the westward, with a narrow trenched rock channel on the north bank. Then there is a long stretch of shaley bedrock ledges, uptilted against the current, with lines of stunted willows growing in the crevices at the edges. Then comes a long deep pool with a copious growth of the red alga, Lemanea, covering the submerged rocks. Then come some more tumbling rapids, that wash the sides of huge rocks—a big flinty rock 25 feet high in midstream, and other grotesquely waterworn blocks in the edges. Then overhead come the "dragon heads" projecting high above the forest on the north bank, the picturesque upstanding edges of vertical thin strata of hard rock. Then in the channel there is a long stretch to the southward with alternating stagnant pools and dry bare rocky river bed.

Doubtless the underground course of this stream is a solution channel formed recently (if we speak in terms of geologic time) by the dissolving of the limestone of the river's bed. For the river flowed on the surface long enough

ONE OF THE BASS POOLS IN THE CACAPON RIVER
THIS AND THE FOLLOWING PHOTOGRAPHS TAKEN BY MISS MYRTLE MILLER.

to cut the mountain ridge in two and to make this sinuous, picturesque, rocky gorge across it. Flood waters still run on the surface, roaring among the bare rocks of the channel that lies all the way in the bottom of this gorge. We visited it at low water, when for more than a mile below the end of Lost River there was no running water to be seen, only a channel lined with bare waterworn rocks, with now and then a residual pool.

It is the aquatic life of this place that is of especial interest because of its abundance and variety. The richest portion of the Cacapon is that covered by our sketch map, the portion near the place where the river emerges; and it is to this that we wish to call particular attention.

ANIMALS

There was nothing remarkable about the vertebrate fauna found at the head of the Cacapon. The following fishes were seen by us:

Hog fish
Black bass
Rock bass
Silver-mouthed minnow
Silver-fin minnow
Spot-tail minnow
Blunt-head minnow
Silver-sides minnow
Cut-lips minnow
Dough-belly minnow
Storer's chub
Sculpin
Johnny darter
Catfish

The only other aquatic vertebrates noted were a few salamanders and a water snake.

The invertebrate fauna was very rich. With screens we collected from among the rocks in the riffles larvae of the following aquatic insects:

Stone-flies

Pteronarcys
Perla
Acroneuria
Peltoperla
Leuctra

May-flies

Heptagenia
Epeorus
Ecdyonurus
Chirotenetes
Leptophlebia
Baetis
Ephemerella
Choroterpes

Caddis-flies

Rhyacophila
Hydropsyche
Philopotamus
Chimarrha
Goera
Leptocerus
Brachycentrus
Psilotreta

Dragon-flies

Argia
Boyeria

Beetles

Psephenus
Dryops
Helichus
Elmis
Stenelmis
Ancyronyx
Macronychus

Two-winged flies

Atherix

Simulium
Chironomus
Coratopogon
Tanytarsus
Eriocera

Tipula

Dobson flies
Corydalis
Chauliodes

In these same riffles, spot-bound on the rocks, there were two curious caddis-worms: Helicopsyche, with its tube of sand grains wound in a spiral, like a snail shell; and Ithytrichia, with its flat lenticular alga-covered case of silk adhering to the upper surface of submerged stones.

Among the rocks at the outflow of the Long Pool (B of map), there was a good growth of fresh-water sponge (Spongilla) and in the osteoles of the sponge we found the little Neuropterous spongilla fly, Climacia, living. The sponge masses were perforated with the tubes of a midge larvae, and furrowed with the tracks of the caddis-worms, *Leptocerus ancylus.*

On the surface of the pools there were whirligig beetles, Dineutes and water striders, Gerris and Rhagovelia, and marsh treaders, Limnobates. In the edges were the usual pond beetles Tropisternus, Hydroporus, etc.; also dragon-flies, Tetragoneuria, etc.; damsel-flies, Enallagma and Ischnura; and caddis-flies, Halesus, Limnophilus, Setodes, Mystacides, etc. A few nymphs of the slender damsel-fly, *Agrion angustipenne,* were found clinging to the swaying leaves of trollops (Heteranthera), swaying in the current.

Bottom sprawlers on the silt and sand were the flat long-legged spider-like dragon-fly nymph, Macromia, the still flatter black Hagenius and the stouter Neurocordulia; also the hairy little silt-covered May-fly, Caenis; also the caddis-worm Molanna, whose flat, wide-winged portable case of sand has an extension, like a portico roof over the front door. Burrowers in the bottom sand were of several groups; the May-flies, Hexagenia, Ephemera and Ephoron; the dragon-flies Lanthus, Gomphus and Dromogomphus; the orl fly, Sialis; the deer-fly Chrysops; the tube-dwelling caddis-worm, Phylocentropus, and the midge, Chironomus.

Hidden in the dense inch-high vegetation that covers the rock ledges at the outlet of the lower bass pool were multi-

THE UPWELLING WATERS OF THE CACAPON,

EMERGING AT THE FOOT OF THE MOUNTAIN AFTER THEIR THREE-MILE COURSE UNDERGROUND.

ISOETES POOL IN THE GORGE ABOVE THE HEAD OF THE CACAPON
ONE OF THE CHOICE COLLECTING SPOTS FOUND BY THE WEST VIRGINIA UNIVERSITY BIOLOGICAL EXPEDITION OF 1930.

tudes of the net-making caddis-worms, Hydropsyche, the May-flies, Ephemerella (2 species), Baetis and Caenis, the midge, Chironomus, the stone-fly, Perla, and the predatory fly, Atherix.

All these animals and others, including a goodly variety of snails, leeches, flatworms and hydrachnids, were found in the two short trips we made to the head of the Cacapon. These are surely sufficient to indicate that it is an exceptionally good collecting ground.

PLANTS

It is quite impossible to gave an adequate word picture of the luxuriant aquatic vegetation growing in the constantly varying habitats of the upper waters of the Cacapon. At every turn in the course of this ever-changing stream one may expect to see in its limpid pools, in the tumbling waters of its noisy cataracts, or in the quieter stretches, something novel and unexpected. The wet rock surfaces and moist sand flats along the border are choice situations for numerous liverworts and mosses.

In the deep pools large masses of algae, *Mougeotia* and *Spirogyra,* hang suspended in the clear, quiet water, suggesting a mirror image of clouds in a blue sky. Where the water tumbles swiftly over rocky ledges there were lush carpets of water mosses covering the rocks, and apparently several species are represented. In the extensive pool (A of the map) just above the falls we came upon a colony of *Isoetes.* Some of these plants were found growing on the sand flats just above the water level but the greater number were found on the rocky bed of the stream, from two to three feet below the surface of the water. At the point where the river emerges from the mountain there is an abundance of the red alga, *Tuomeya.*

In the shallower parts of the river and along the banks, particularly where the fringing trees or rock walls do not exclude the sunlight, there are extensive beds of *Potamogeton* and *Heteranthera.* Caught in the meshes formed by the branches and leaves of these plants there were great numbers of dark-green, irregularly vesicular, algal bodies which, when examined, were found to be specimens of *Nostochopsis lobatus.* This alga grows very loosely attached to the rocks, and since this attachment is easily broken, these plants are commonly found floating on the water behind logs, rocks or other obstructions, such as floating vegetation. In several places we found the flat, leathery, disk-like thalli of *Nostoc muscorum* growing on the surface of the rocks in shallow water, and these plants were objects of very special interest to the entomologists of our party, for there was found a midge larva dwelling inside almost every plant examined. Another blue-green alga, *Oscillataria tenebriformis,* occurs here in abundance. This is a most interesting species of Oscillatoria in which the terminal portion of the filaments coils up to form a very close spiral. *Spirogyra crassa,* one of the giant forms of the genus, thrives here and can be collected in quantities.

At a point near the island (just above C on the map) there is a splendid colony of *Marchantia polymorpha.* Some of these plants are growing on the damp soil near the river margin but the larger and finer specimens are almost completely submerged. Here where the water flows over these plants the thalli attain a diameter of eight to ten inches, and produce numerous, large cupules. At the outflow from the long pool (B of the map) near the bed of the fresh-water sponges, we found a species of *Utricularia,* but as we were unable to find any flowers or fruits we could not identify it with any degree of certainty.

No attempt has been made to secure any precise data concerning the composition of the aquatic flora of this restricted area, but perhaps the preceding paragraphs will suffice to give some little conception of how rich and varied this plant life really is. In order that the algologist, the bryologist or any other botanist may get a better idea of the composition of this aquatic flora, a brief statement is given here concerning the entire plant population.

Twenty genera of algae are growing here including blue-green, green and red algae, and a number of these genera are represented by more than one species. For example, Dr. R. C. Spangler, professor of botany in West Virginia University, to whom we are indebted for the identification of the algae, reported two species of Spirogyra, two species of Anabaena and five species of Oscillatoria. Miss Nelle Ammons, instructor of botany in West Virginia University, who identified the bryophytes, reported fourteen genera of liverworts and twenty-four genera of mosses involving a total of forty-nine bryophyte species. On the rocky slopes just out of the water and along the banks elsewhere there were found eleven species of pteridophytes, and more than a hundred species of typical fringing herbs, shrubs and trees. Doubtless an intensive study of this entire situation will reveal a number of species not observed by us in this first, hasty survey.

This wonderful region is now (1930) very easily visited. The best approach is over the well-graded road eastward from Moorefield. This highway crosses the mountain called Sandy Ridge just before reaching the village of Wardensville. A stone-throw above the river bridge, at the western foot of the slope and easy of approach on foot, is the place where Lost River sinks underground. Passing on over the mountain, just at its foot on the eastern side, perhaps a mile before reaching Wardensville, there is an obscure path running northwestward down the slope to the river. This path quickly leads to the portion of the Cacapon shown in our map. Just above the first trestle where the log railway crosses the river and within half a mile of the highway is one of the most interesting portions of the Cacapon. This railway parallels the river all the way through the gorge, making all points in it easy of access.

SPEAKERS AT THE DINNER GIVEN TO SIR JAMES HOPWOOD JEANS

SIR JAMES HOPWOOD JEANS; PROFESSOR MICHAEL I. PUPIN, PROFESSOR OF ELECTRO-MECHANICS AT COLUMBIA UNIVERSITY, AND DR. W. F. G. SWANN, DIRECTOR OF THE BARTOL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE. THE SCIENTIFIC MONTHLY WAS ONE OF THE SIX ORGANIZATIONS SPONSORING THE DINNER TO SIR JAMES, AND IT HAS THE PRIVILEGE OF PRINTING THE DINNER ADDRESSES IN THIS NUMBER.

THE PROGRESS OF SCIENCE

THE NEW PRESIDENT OF THE NATIONAL ACADEMY OF SCIENCES

DR. WILLIAM WALLACE CAMPBELL, who was elected president of the National Academy of Sciences by the unanimous vote of the members present at the annual meeting of the Academy on April 29 is the first astronomer to hold that high office. Three of his eleven predecessors—Alexander Dallas Bache, Joseph Henry and Albert Abraham Michelson—were distinguished physicists; three—William Barton Rogers, Othniel Charles Marsh and Charles Doolittle Walcott—geologists and paleontologists, and two—Wolcott Gibbs and Ira Remsen—chemists. Of the other three, Dr. William Henry Welch is known as a pathologist and physician, Dr. Thomas Hunt Morgan as a biologist, while Alexander Agassiz was both a geologist and an engineer.

The office is an honorable and an important one, not only because the membership of the academy is drawn from men of the highest standing in the various fields of scientific research, but also because the academy is the official advisory body to the Government of the United States on all scientific questions. When such questions are referred to the academy by the government, it is the duty of the president of the academy to appoint committees to investigate them, composed of members specially conversant with the subjects, to call in experts from the outside when he deems it necessary, and to act, ex officio, as member of all such committees. In addition to being a man of distinction in his own field of scientific research, therefore, he should also be a man of sound judgment and of broad experience in administrative and executive work.

In all respects, Dr. Campbell is fully qualified to meet the requirements of his new office. Coming to the Lick Observatory as astronomer in 1891, only three years after the observatory was transferred to the regents of the University of California, he was already known for his work in orbit computation and as a teacher of mathematics and practical astronomy. Here, he recognized the opportunity that was presented for applying photography to the investigation of stellar spectra, and, in particular, to the accurate measurement of the wave-lengths in such spectra, and therefore of the radial velocities of the stars or nebulae whose light they analyze. How well he improved that opportunity can not be related in detail here, but will be apparent to any one who will examine his book on "Stellar Motions"[1] or the Lick Observatory Bulletins and the volumes of the Lick Observatory Publications that are devoted to radial velocity results. True, Dr. Campbell did not do all this work alone; he had a number of able collaborators and many assistants; but he planned the work, set the standard, and in large part designed the instruments and developed the methods of observation and reduction, in addition to initiating and participating in the actual observing. The accuracy of the radial velocity results secured by him in 1896 with the original Mills spectrograph has not been surpassed anywhere even to this day. As to the importance of the results, it is not too much to say that the radial velocity work begun with the Mills spectrograph and 36-inch refractor at Mount Hamilton in 1896 and continued through the years there, and until 1928 at the station on Cerro San Cristóbal, Chile, constitutes the opening paragraph and some of the most significant later ones

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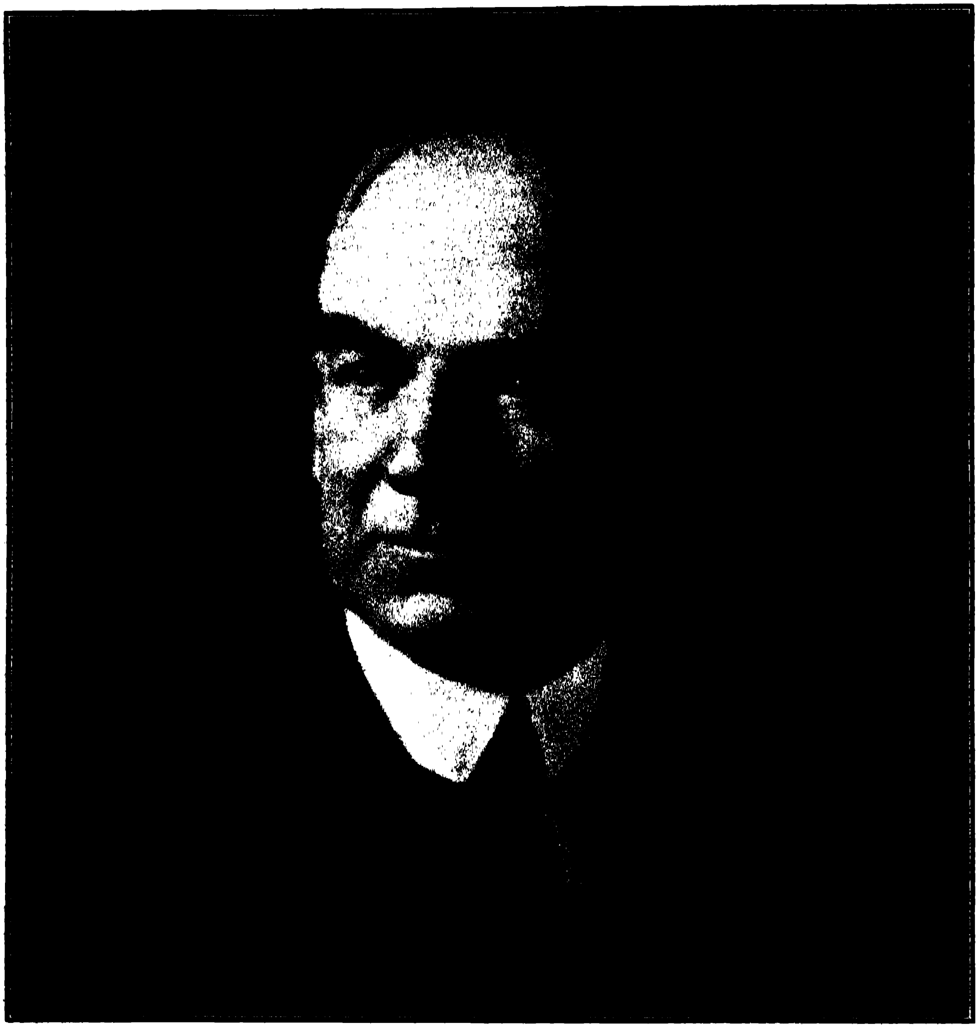
[1] The Silliman Lectures, Yale University, for 1913.



DR. W. W. CAMPBELL

in what is one of the largest chapters in the history of modern astronomy.

The first total eclipse of the sun observed by Dr. Campbell was the one at Jeur, India, in 1898. Thoughtful study of the problem he had set himself to solve, thorough preparation, with careful attention to details, combined with observing skill and resourcefulness in emergencies—and, of course, clear skies—brought success on this expedition. This was repeated at the eclipses of 1900 (Georgia), 1905 (Spain), 1908 (Flint Island), 1918 (Goldendale, Washington) and 1922 (Australia). The only failure was in 1914, at the Russian eclipse, and that was due entirely to clouds. A volume[2] is in press at the present time which gives an analysis of the flash-spectrum plates secured by Dr. Campbell at several of these eclipses, and, in particular, at the one in 1905, by means of the moving-plate spectrograph, a novel instrument of his own design, which has the great advantage of giving a continuous record of the

[2] By Dr. D. H. Menzel, with an Introduction by Dr. Campbell.

spectrum of the chromosphere, as the moon gradually covers or uncovers it.

The particular problem at the 1922 (Australia) eclipse was to test, observationally, Einstein's prediction of the deflection of light in passing through the sun's gravitational field. Dr. Campbell designed the telescopes for this work with special care, to eliminate, so far as this was possible, errors from instrumental sources, and, with Dr. R. J. Trumpler's collaboration, carried out the program successfully. The observed deflection of starlight, in amount, and in the law of variation with increasing distance from the sun's limb, was in complete agreement with Einstein's prediction.

In 1900, the untimely and lamented death of Dr. James E. Keeler left the position of director of the Lick Observatory vacant. President Benjamin Ide Wheeler, of the University of California, in his search for the best man to succeed Dr. Keeler, wrote to the leading astronomers of America and Europe for nominations. Without exception, they all named Dr. Campbell! On January 1, 1901, he entered upon the duties of this office, an office he continued to hold until June 30, 1930, although for the seven years following July 1, 1923, he had to delegate to an associate director the active administration.

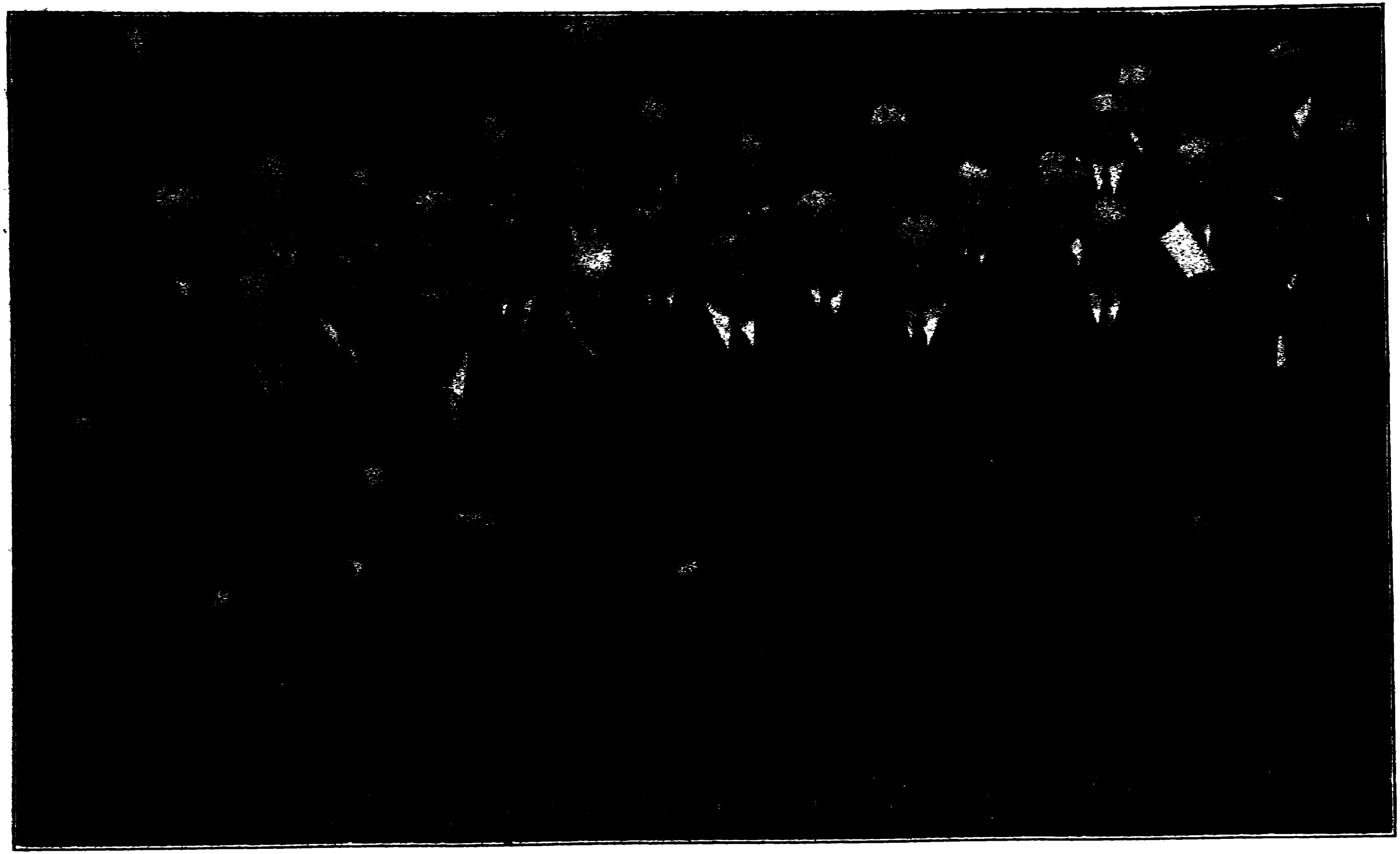
It was in that year, 1923, that he was called upon to assume the presidency of the university. He did not seek the office; indeed, when, immediately upon his return from the Australian eclipse, it was offered to him and urged upon him, he replied that he did not want it; that his highest ambition was to remain on Mount Hamilton as director and astronomer in the Lick Observatory. In the end, he found it his duty to accept, and how successful his administration was can best be shown by quoting the short address tendered to him by the Academic Senate of the university on October 7, 1929.

> It is with profound regret that the Academic Senate has learned of your approaching retirement from the Presidency.
>
> The extraordinary genius for organization previously demonstrated in the development of the Lick Observatory, in many eclipse expeditions, and in bringing about international cooperation among astronomers has made your present office a model of business efficiency. Every problem presented by a university department has been answered promptly and without ambiguity.
>
> You have surrounded yourself with an unusual group of wise councillors and able executives in whose judgment the faculty has had confidence.
>
> In the midst of complex external problems and great material development, your administration has not been diverted from the main purpose of a university, the advancement of teaching and of learning. The departments have been strengthened by the addition of men of distinction and by increased facilities for productive scholarship.
>
> Your administration has been a period of tranquility and healthy growth such as few universities have enjoyed, and we, the Academic Senate, desire to express to you our heartfelt appreciation.

On June 30, 1930, Dr. Campbell retired from active service in the university, becoming President Emeritus and also Director and Astronomer Emeritus.

Space limitations forbid more than the mere mention of such facts as that Dr. Campbell was most active in organizing the International Astronomical Union, in 1919; that he served as president of the Union for the period 1922–1925; that he has been president of the American Association for the Advancement of Science, of the American Astronomical Society and of other scientific societies; and that his work has won recognition and honors in the form of medals, honorary degrees and other distinctions from universities and scientific societies at home and abroad. He brings to the office of President of the National Academy of Sciences the ripened judgment and wisdom gained from long years of distinguished service as a man of science and as an executive.

ROBERT G. AITKEN



MEMBERS OF THE NATIONAL ACADEMY OF SCIENCES

Brown, E. Kettering Squier White, H. S. Saunders
Bowman Osborn Davis
Millikan Bowie Kellogg Crew Henderson Kennelly Trowbridge
Clarke Boas Cross Blakeslee Coblentz Adams, F. D. Keith Bogert
Hudson Levene Mendenhall Compton, K. T. Campbell, W. W.

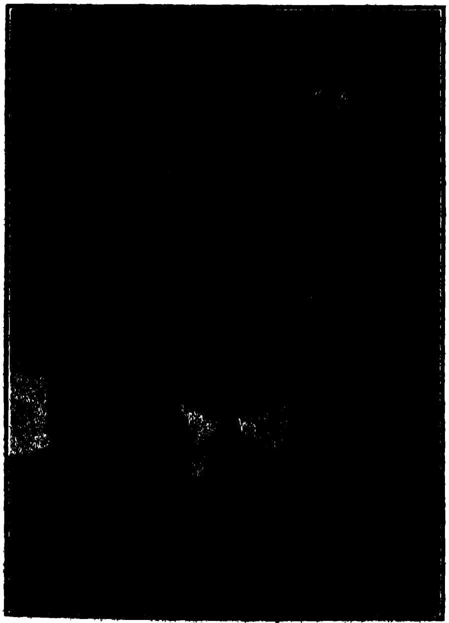
THE SPRING MEETING OF THE NATIONAL ACADEMY OF SCIENCES

The National Academy of Sciences was established by an Act of Congress, approved on March 3, 1863, by President Lincoln, to serve as adviser to the Government whenever called upon by any department of the government to "investigate, examine, experiment, and report upon any subject of science or art." This is a severe demand to make upon any organization and one that can be adequately met only by a membership of high standing. Viewed from this standpoint, election to the Academy means that, in the opinion of the Academy members, the new member is competent to serve the Academy effectively in case he should be called upon to do so. Each year at its annual meeting the Academy thus does honor to a number, not exceeding fifteen, of American scientists by electing them to membership.

The Academy holds two meetings each year, the annual meeting in April in Washington and the autumn meeting elsewhere. At each meeting there are open public sessions for the reading of scientific papers; also business sessions of the Academy attended by members only.

The constructive work of the Academy is done by committees of members having special qualifications for the work in hand. There are 17 standing committees of this nature; and in addition 18 committees for the administration of the different trust funds belonging to the Academy.

A special agency of the Academy is the National Research Council which was established in 1916 at the request of President Wilson. An Executive order, dated May 11, 1918, directed the Academy to perpetuate the Research Council for the performance of certain duties specified in the order. The National Research Council seeks "to promote research in the mathematical, physical and biological sciences and in the application of these sciences

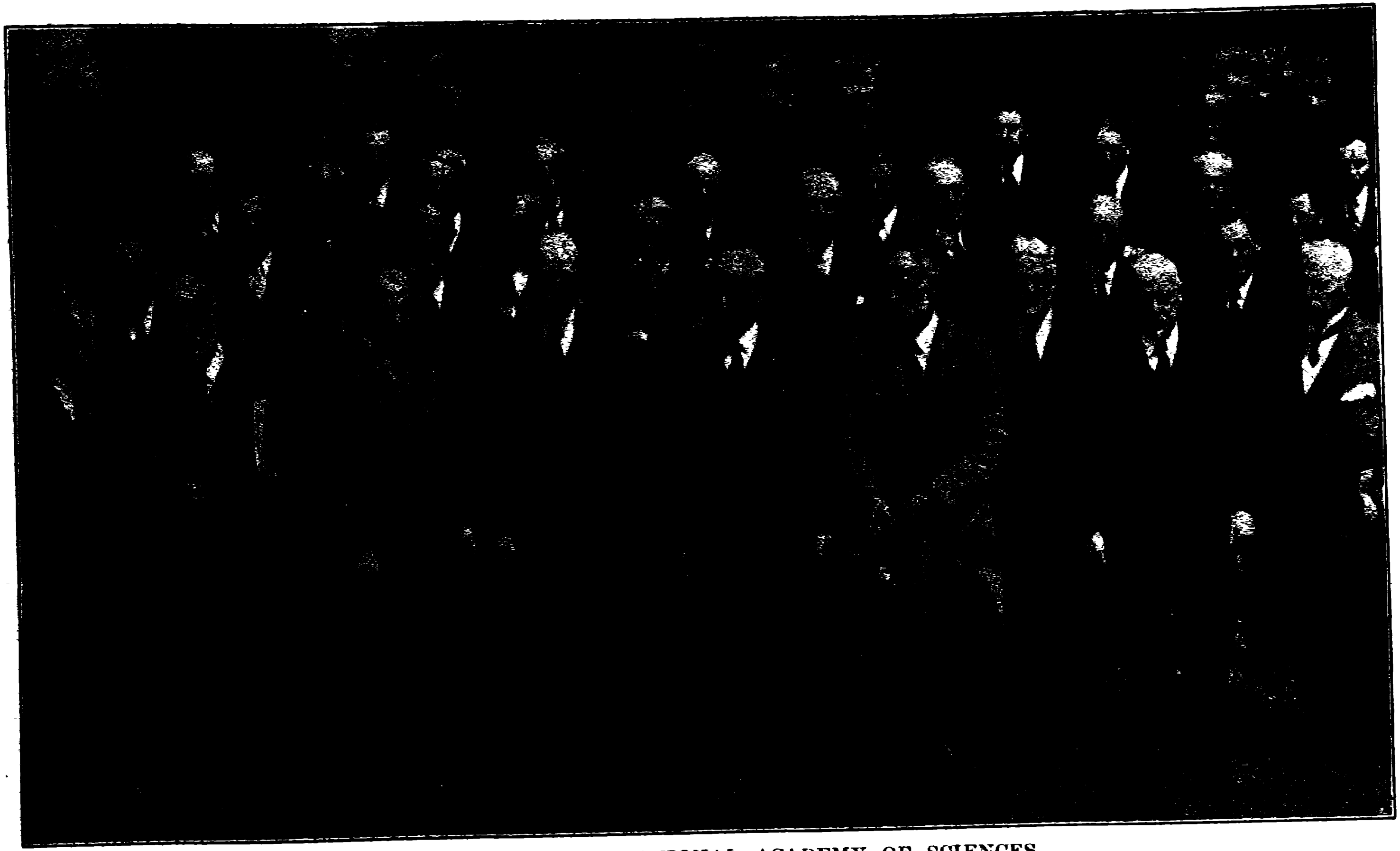


R. L. MOORE, PH.D.

PROFESSOR OF MATHEMATICS,
UNIVERSITY OF TEXAS.

E. C. KEMBLE, PH.D.

ASSOCIATE PROFESSOR OF PHYSICS,
HARVARD UNIVERSITY.



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to engineering, agriculture, medicine and other useful arts, with the object of increasing knowledge, of strengthening the national defense and of contributing to the public welfare." To this end "membership in the Council is chosen with a view of rendering the council an effective federation of the principal research agencies in the United States concerned with these fields of science and technology." The Research Council has its own officers and membership and, within certain limits, determines its own policies and activities.

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DIRECTOR OF THE DEPARTMENT OF EMBRYOLOGY,
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The disbursements of the Academy, including the National Research Council funds, during the fiscal year, 1929–1930, totaled nearly $1,200,000; of this amount approximately one million dollars was for projects of the National Research Council; more than one half of this sum was for fellowships and grants-in-aid in the mathematical, physical and biological sciences.

This outline of the activities of the Academy and its allied agencies suffices to indicate that election to the Academy implies the acceptance of definite responsibility by each member to aid in carrying on the work of the Academy.

At the recent meeting of the Academy held in Washington on April 27 to 29 the following officers were elected for a period of four years:

President, W. W. Campbell, **of the University of California and Lick Observatory.**

Vice-president, David White, **of the United States Geological Survey.**

Home Secretary, F. E. Wright, **of the Geophysical Laboratory of the Carnegie Institution of Washington.**

Two new members of the council were elected for a period of three years:

W. B. Cannon, of Harvard Medical School.

Roger Adams, of the University of Illinois.

One foreign associate was elected:

P. Debye, of the University of Leipsic.

The new members elected were:

Henry Bryant Bigelow, Professor of Zoology, Harvard University and Director of the Woods Hole Oceanographic Institution.

Edwin Broun Fred, Professor of Bacteriology, University of Wisconsin.

Edwin Crawford Kemble, Professor of Physics, Harvard University.

Adolph Knopf, Professor of Geology, Yale University.

Robert Harry Lowie, Professor of Anthropology, University of California at Berkeley.

Joseph Haines Moore, Astronomer at Lick Observatory.

Robert Lee Moore, Professor of Mathematics, University of Texas.

Hermann Joseph Muller, Professor of Zoology, University of Texas.

George Linius Streeter, Director, Department of Embryology, Carnegie Institution of Washington at Baltimore.

Margaret Floy Washburn, Professor of Psychology at Vassar College.

Two medals were awarded at the annual dinner:

M. F. WASHBURN, PH.D.
HEAD OF THE DEPARTMENT OF PSYCHOLOGY,
VASSAR COLLEGE.

The *Daniel Giraud Elliot* medal for the year 1929 to *Henry Fairfield Osborn*, of the American Museum of Natural History, for his Monograph No. 55 of the United States Geological Survey on the Titanotheres of Ancient Wyoming, Dakota and Nebraska. The presentation speech was made by *W. B. Scott*, of Princeton University.

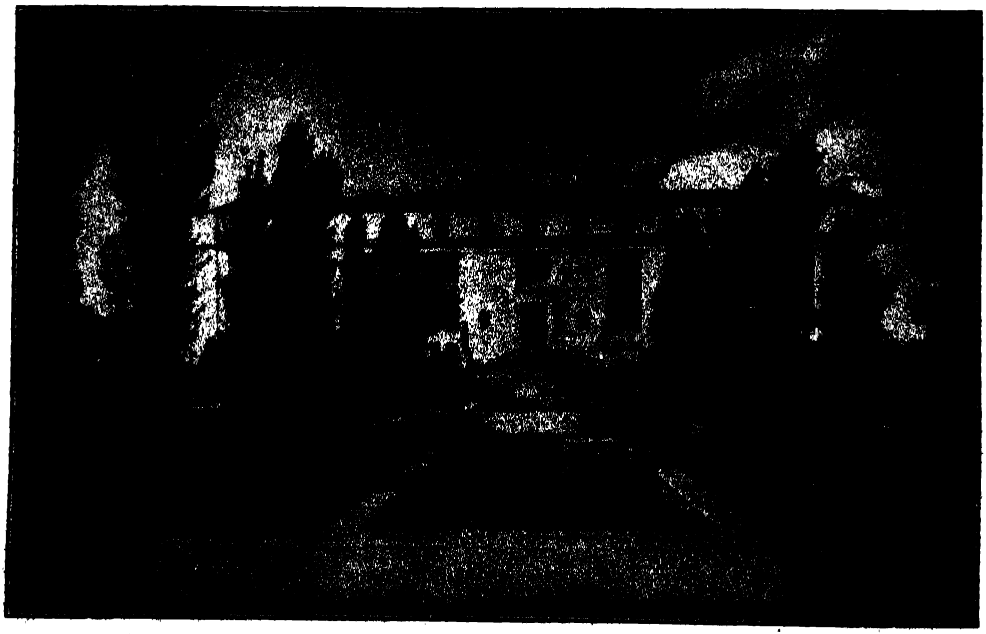
The *Mary Clark Thompson* medal to *Edward Oscar Ulrich*, of the United States Geological Survey for outstanding contributions to geology and paleontology, especially of the Paleozoic of America. The presentation speech was made by Rudolf Ruedemann of the New York State Museum at Albany.

At the open scientific sessions 49 papers were read. The distribution of the papers among the sciences was: Astronomy, 3; Mathematics, 2; Engineering, 3; Physics, 12; Geology, Paleontology and Geophysics, 6; Chemistry, 3; Anthropology and Psychology, 2; Zoology and Biology, 10. The Monday evening Public Lecture was delivered by James H. Breasted, Director of the Oriental Institute of the University of Chicago, on "The Rise of Man and Modern Research." This extremely interesting lecture was attended by 660 people, the capacity of the Auditorium of the Academy building. At the scientific sessions the average attendance was 250. Attending the business sessions were 107 members of the Academy, out of a total membership of 253.

During the sessions Academy members and visitors viewed the exhibits set up in the rooms surrounding the Auditorium. This exhibition is maintained throughout the year and seeks to illustrate, in understandable form, certain fundamental principles of science. It is one of the outstanding features of the Academy building and is viewed by forty to fifty thousand visitors each year. The building itself is monumental in character and classical in design and is located on Constitution Avenue facing the Mall near the Lincoln Memorial. It is the home of the National Academy of Sciences and the National Research Council and is in keeping with the high purposes and functions of the Academy.

The autumn meeting of the Academy this year will be held on November 16 to 18 at Yale University.

F. E. Wright,
Home Secretary



THE BUILDING OF THE NATIONAL ACADEMY OF SCIENCES

THE SCIENTIFIC MONTHLY

AUGUST, 1931

BIOLOGICAL OPPORTUNITIES IN SIAM

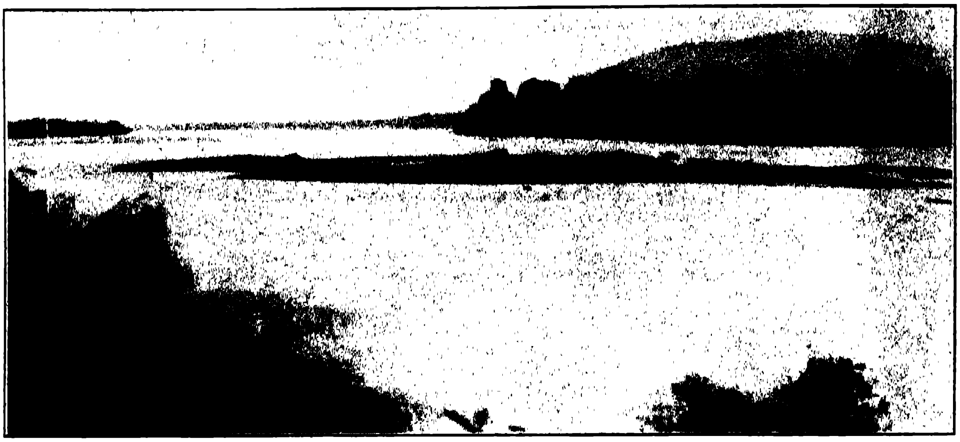
By Professor **GORDON ALEXANDER**

FORMER VISITING PROFESSOR OF BIOLOGY, CHULALONGKORN UNIVERSITY

It is a significant commentary on biological opportunities in Siam that, until recently, the only facts the average individual could readily associate with the country were biological. Siam, since the height of Mark Twain's fame, has been the home of the "white" elephant, and that mysterious land from which came the original Siamese Twins. Only in the past few years have increasing ease of travel and moving pictures, as travel substitutes, broadened this viewpoint. Now the layman associates additional and more significant facts with Siam. Politically and socially the country is slowly coming closer to us. Her government is described for us over the radio by His Serene Highness, the Minister from Siam, while we have read in the newspapers of the visit of Their Majesties to the United States. Our original picture is fading in favor of a saner and fairer one. We have all thought that Siam must be, for the most part, a hinterland of dark jungle, inhabited largely by elephants and tigers and apes, where man exists only through a supreme but very close-to-nature cunning! Our imagination has been extravagant. Siam is not a savage land. This does not mean, however, that she is not and will not be for years to come a land of opportunity for the biologist.

The biologist's interest in Siam to-day is other than in the Siamese Twins, who passed away in 1874, or in the two, present-day, albino elephants housed in the stables at Dusit Park. It is in her rich fauna and flora. The fauna and flora, rich as they are, are still in many respects virgin to scientific investigation. Siam is not all jungle, and most parts are far more readily accessible than one imagines, but many of her groups of animals and plants have hardly been studied even by the field man—usually forerunner of all the rest. If there yet remain any of the admirable group described as "naturalists," Siam is still their happy hunting ground.

Not the least of the factors making for increased opportunity in Siam to-day is improved methods of transportation. The days of weary tramping through "untracked jungle," week on end, are about ended in Siam. Modern transportation is so rapidly coming to man's assistance that there is no longer the former great difficulty in reaching out-of-the-way sections of the kingdom. From Padang Besar, on the border of Kedah, to Chiengsen Kao, on the Mekong, almost a thousand miles away in a direct line, and in the east and northeast to Nong Kai or Ubon, are connecting railways or roads. My wife and I traveled from Padang Besar to Chiengsen Kao, some twelve hundred miles by rail and road, in less than three days actual traveling time. Twenty years ago it might have taken as many months. Padang Besar is on the south-



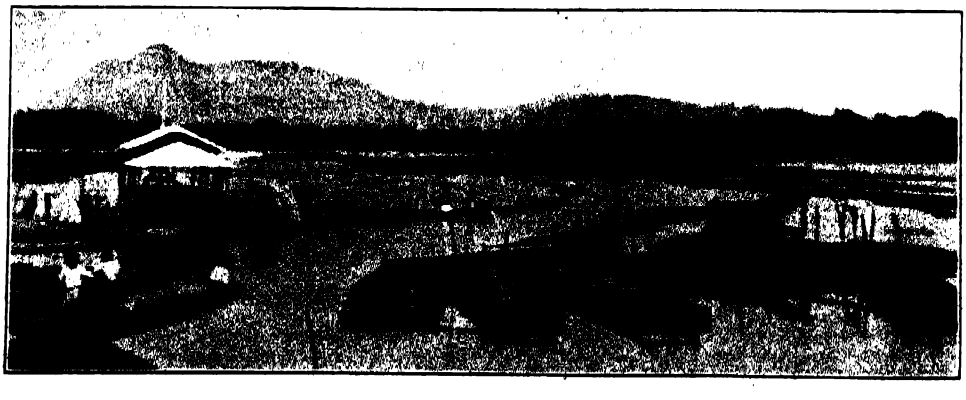
THE MEKONG AT CHIENGSEN KAO

A MAGNIFICENT RIVER, EVEN HERE, 1,500 MILES FROM ITS MOUTH.

ern boundary of peninsular Siam, Chiengsen Kao is almost the farthest north point of Siam. Even Nan, where the movie "Chang" was filmed several years ago, we were able to visit by motor car. A dry-weather road was opened in February, 1930, from the nearest railway point, some eighty miles to the southwest.

Along the coasts of the Gulf, one can easily make arrangements to be landed at desired points on the mainland or islands from one of the several comfortable steam or motor ships of the Siam Steam Navigation Company. In this way the writer and Nai Siri Habananda, also of the department of biology of Chulalongkorn University, were able to spend several days with Dr. A. S. Pearse in observation on Koh Chang, the largest Siamese island in the eastern portion of the Gulf.

In addition, there is the air. Siam is not backward in aviation, for she has her own aeroplane factory and manufactures some fifty planes each year. Some foreign visitors have already used aeroplanes to reach certain outlying dis-



THE MENAM MEKOK AT CHIENGRAI

A TRIBUTARY OF THE MEKONG. THE RAFTS IN THE FOREGROUND ARE OF BAMBOO, A MOST VERSATILE WOOD AS USED BY THE SIAMESE.

THE RICE PLAIN OF NAN

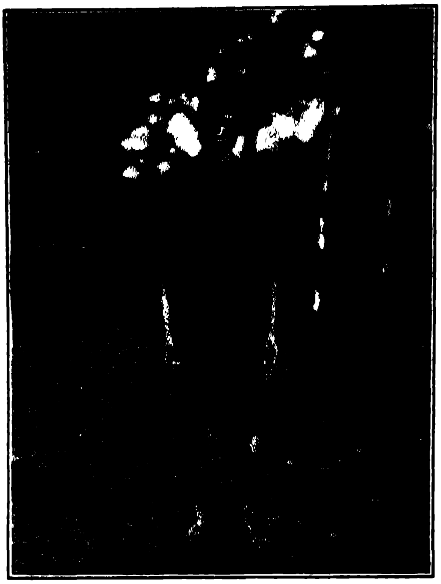
THE PLAIN OF THE NAN RIVER, NORTHERN SIAM, SUPPORTS A CONSIDERABLE POPULATION.

tricts, but the cooperation of the government is necessary. Where modern transportation fails, and that is usually relatively near one's destination, one simply resorts to the only methods of the past, travel on foot or on horseback or in dugouts. Reliable and peaceful local carriers or polers are available. However, it is a great advantage that most of the sections one wishes to visit are readily accessible by modern, rapid means of transportation; but the improvements in transportation will, one may be sure, rapidly bring about changes in the natural conditions themselves. This change has, in fact, already begun.

The visitor in Bangkok may be surprised to find that his English is quite sufficient, providing he adapts it to his audience, and forgets any native pigheadedness he may possess. This is not

THE NAN RIVER AT NAN

THE RIVER MAY BE FORDED ON FOOT DURING THE DRY SEASON, AT WHICH TIME THIS PHOTOGRAPH WAS TAKEN.



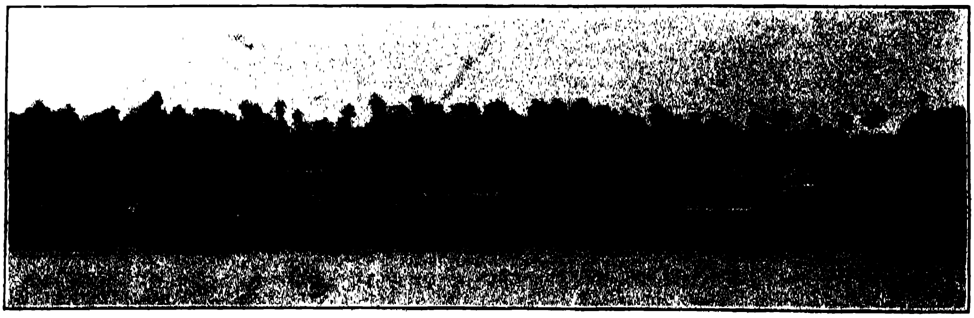
A LAO OF NAN

THIS MAN ASSISTED ME IN SKINNING BIRDS, DURING OUR WEEK IN NAN.

so true in the back country. The Siamese who speak English, even of the official class, are relatively less numerous outside Bangkok. The atmosphere of the capital city is more cosmopolitan; that of the countryside, distinctly Siamese. The traveler in the interior of Siam should have an interpreter, unless he himself can speak Siamese in some form, and with considerable ease. One could, perhaps, but not to such advantage, substitute one of the principal dialects of southern China. Certain forms of Chinese are widely spoken in Siam by natives of southern China, who, after having emigrated there, have penetrated to even the most remote jungle villages. On the other hand, inability to speak the language of the Siamese does not make life with them the more unpleasant. They are an exceedingly polite people. The bond of sympathy which comes from ordinary good nature, good humor and the use of the universal sign language is quickly established.

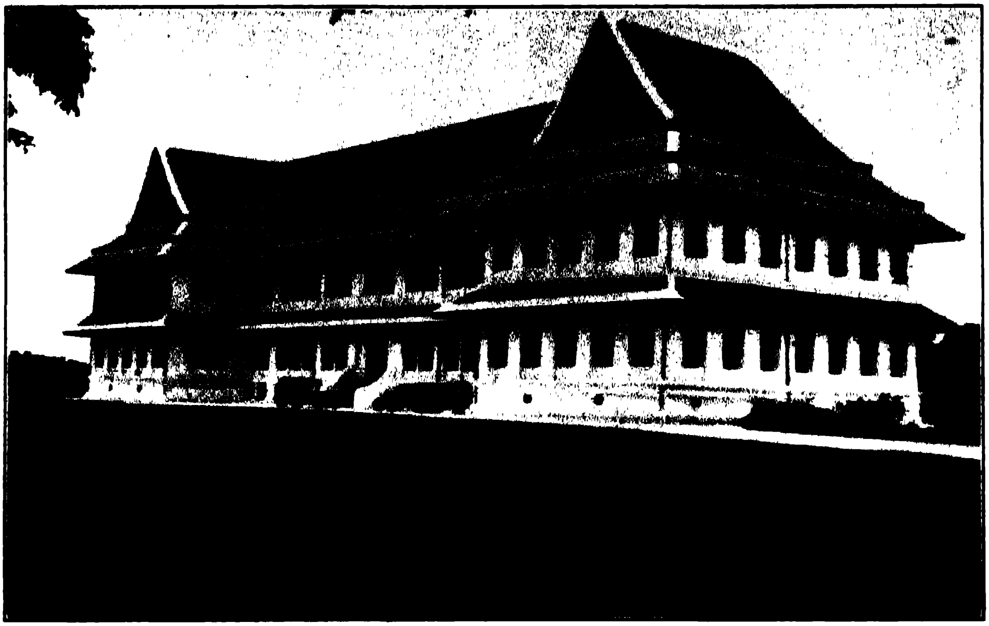
Some months ago an incident occurred which demonstrated this in a forceful way. A young English girl, through some unknown cause, fell from the window of her railway compartment in the International Express from Singapore to Bangkok. The accident occurred at night, and she was not missed by her parents until the next morning, still a half-day south of Bangkok. When the frantic father found her that evening, many miles to the south, through the telegraphic inquiries of the railway officials and special transportation which they provided, she had been fed and taken care of by some Siamese farmers who had found her, and except for a shaking up and a cut where she was injured in falling, she was perfectly safe. She had known not a word of Siamese, but had experienced the boasted hospitality of the Siamese peasant.

The visitor has little occasion to fear



THE BANK OF THE MENAM CHAO P'YA BELOW BANGKOK

NIPA, ARECA AND A FEW COCONUT PALMS MAY BE RECOGNIZED. THE OTHER TREES ATE MANGROVES.



THE SCIENCE BUILDING, CHULALONGKORN UNIVERSITY

SIAMESE UNIVERSITY STUDENTS

THE BIRDS ARE GIANT HORNBILLS
These specimens of *Dichoceros bicornis* (L.) were taken on Koh Chang, a large island in the Gulf of Siam. The man wearing the beret is Nai Siri Habananananda, a biologist of Chulalongkorn University.

for his safety in Siam. I think we are less safe, in many ways, in America. Certain types of disease must be continually guarded against, but, through eternal vigilance, the danger from these is greatly lessened. The chief "racketeers" are still political grafters, and there are plenty of such, even in an absolute monarchy! The animals that may harm man are not abundant, and the very conditions that are associated with improved methods of transportation have made for their reduction. The one hundred per cent. conservationist regrets this, but the residents of a village in which as many as twenty human beings have been killed by tigers in a single year do not. And these native villagers are generally without fear, according to our standards.

Of immeasurable assistance to all foreign visitors in the interior, and always to be considered in one's plans, are the missionaries. Many isolated sections are perfectly familiar to representatives of one of the mission organizations, and these men are often extremely generous in their assistance of field biologists. Of these groups, of chief importance and largest in point of numbers, is that composed of the members of the American Presbyterian Mission. These are concentrated in northern Siam, but there are a few representatives also in the peninsular portion of the country. It was the privilege of my wife and me to spend some three weeks in February and March in northern Siam. We visited Chiengrai, Chiengsen, Chiengmai, Nan and Prae, and in every place enjoyed the hospitality of American missionaries who were active in helping us secure information, photographs or specimens which we wished. The missionaries usually enjoy contacts with outsiders, but the obligation is certainly not theirs. Why a "professional" traveler should

A LAO HOME
A few miles northwest of Chiengrai.

IN THE MOUNTAINS NORTHWEST OF CHIENGRAI

Evergreen forest occurs in parts of northern Siam. This photograph was taken at an elevation of about 1,500 feet.

expect to express his whole thanks in terms of an autographed copy of his latest book, or a water-color sketch of the banana trees in one's compound, as some do the world around, is unaccountable. The comforts of life he has enjoyed are so inaccessible to his host that the latter, who may live five hundred miles from his nearest "American" grocery store, is considerably out of pocket and larder. I think the visiting scientist at least recognizes his obligation, for nearly every report of scientific collections in northern Siam includes acknowledgments to members of the missionary group.

One may gather from the above remarks that Siam is much more accessible than the work of field biologists up to date would indicate. This, in fact, is true. The fauna, as a whole, has not yet been well collected. The more primitive phyla are hardly known. No more than introductory studies have been made on the plankton, either fresh-water or marine. Little actually is known of the variety of invertebrates in the Gulf of Siam. More is known of the larger, fresh-water invertebrates, but the incomplete studies of a few groups have already yielded such a variety of forms that it is obvious that these very studies have not been exhaustive. For example, a paper appears on the river crabs of Siam. Several new varieties are described, these of very limited distribution—the streams of one small mountain, say. Yet extensive portions of the country are not represented in the collections studied, and one can only guess that higher and more inaccessible mountains somewhere else, unvisited, may yield still other forms.

Dr. Hugh M. Smith has collected more than fifty species of shrimps of commercial value in Siam; and has said that it "seems altogether probable that in no other country do shrimps exist in greater profusion."[1] An unbelievable

A PALM GROVE ON KOH CHANG

Draco was numerous in this grove, and Dr. Pearse collected one specimen of *Ptychozoon*.

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[1] Hugh McCormick Smith, "A Review of the Aquatic Resources and Fisheries of Siam, with Plans and Recommendations for Their Administration, Conservation, and Development." Bangkok: Ministry of Lands and Agriculture, 1925.

A MALAY FISHING VILLAGE IN THE INLAND SEA

MALAYS BECOME VERY NUMEROUS AS ONE APPROACHES THE SOUTHERN BORDER OF SIAM.

variety of these crustaceans has been reported from the Inland Sea alone, a body of water in peninsular Siam, about sixty miles long, and having a marked gradient of salinity from its brackish southern end to the fresh water of the northern end. No one has yet properly taken advantage of the possibility here to study the influence of this interesting saline gradient in the distribution of life in the Inland Sea, whose fauna is remarkable in many other ways than in the abundance and variety of shrimps. But, naturally, little ecological study can be accomplished until the fauna itself is better known. Certainly, present work on invertebrates can not be considered "monographic," especially since the fauna of Bangkok itself is comparatively unknown.

It is quite apropos, in this connection, to refer to the recent remarks of two American scientists in the Orient[2] re-

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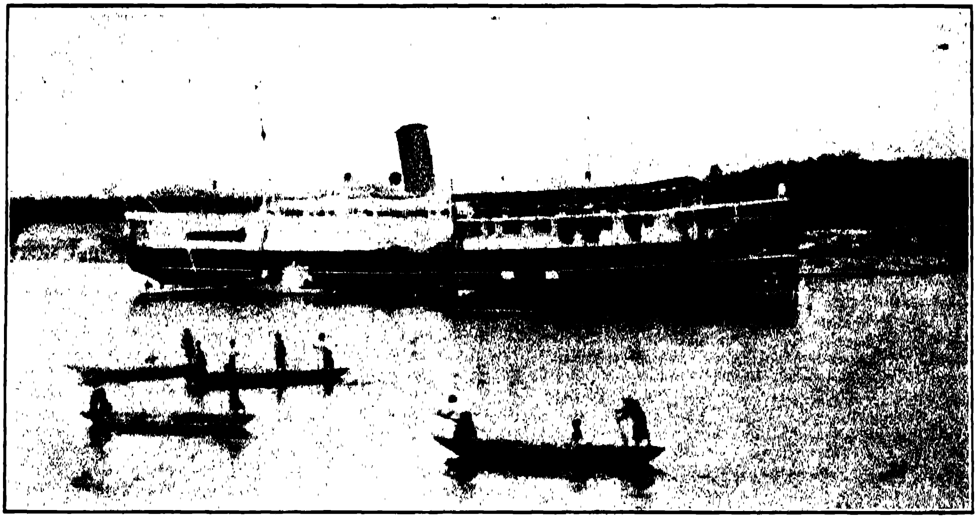
[2] G. E. Gates, *Science*, 70: 266–267, September 13, 1929; A. P. Jacot, *Ibid.*, 73: 11–12, January 2, 1931.

COCONUT PALMS ON AN ISLAND IN THE INLAND SEA



A MOTOR SHIP OF THE SIAM STEAM NAVIGATION COMPANY

THIS VESSEL IS AT THE PIER IN THE CHANTABOON RIVER, SOUTHEASTERN SIAM.

garding the ease with which we overlook our fauna. It is not an accident that both of these men happen to be students of an exotic fauna. Their eyes have been sharpened through a taxonomic exercise the average biologist does not get. If our fauna is so little known—and how can it be otherwise in the present feverishly experimental cycle?—how much less known is the fauna of a country where biological students have always been rare? Perhaps the Siamese will not put the cart before the horse, and will, to take a simple example, really find out what *Euglena viridis* Ehrbg. looks like before experimenting with another species of Euglena under the impression that it is the old tried-and-true form pictured in all the textbooks! It is to be feared, however, that our bent for experimenting with organisms of whose names, even, we are ignorant, is being rapidly communicated to them.

If there is any group of Siamese invertebrates fairly well known it is that which includes the butterflies. Over seven hundred forms have been identified, and a list of these has but recently appeared.[3] The moths, however, are not so thoroughly known. In a collec-

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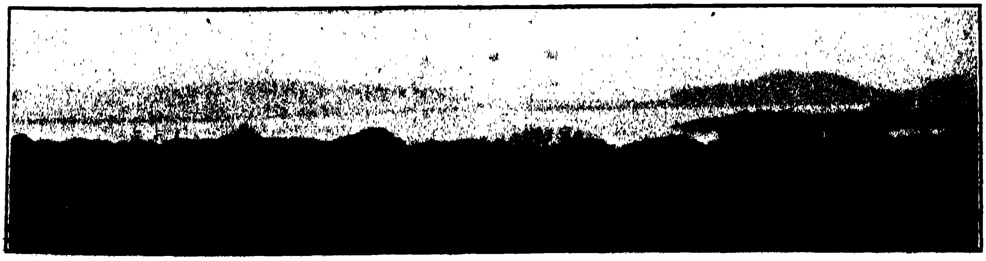
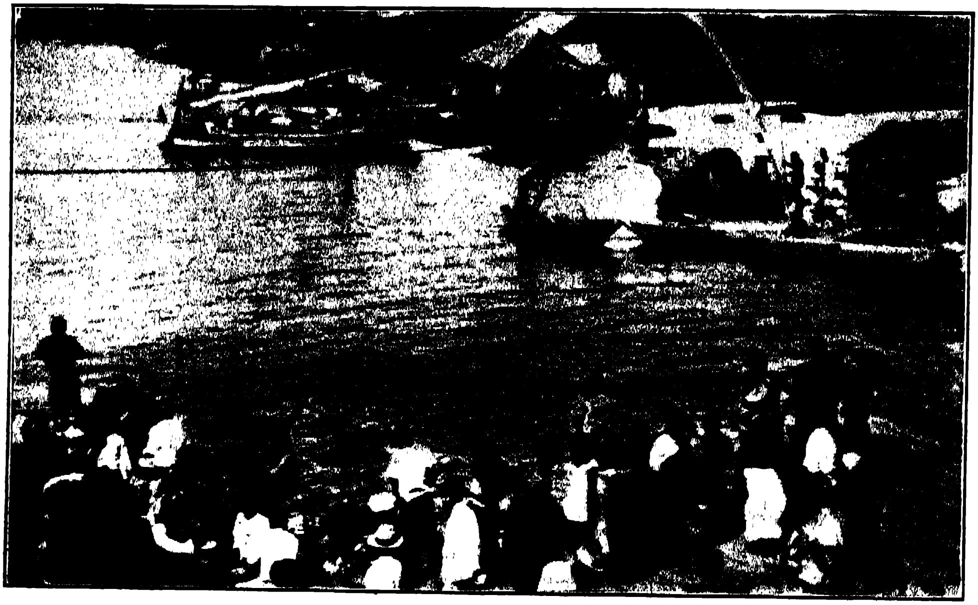
[3] E. J. Godfrey, "A Revised List of Siamese Butterflies," *Jour. Siam Society*, Natural History Supplement, 7: 203–397, 1930.



THE INLAND SEA FROM THE SOUTH

THIS PHOTOGRAPH, TAKEN FROM A SMALL HILL, LOOKS ACROSS THE CITY OF SINGORA, WHICH IS CONCEALED BY THE TREES.



ON THE CHANTABOON RIVER, SOUTHEASTERN SIAM
THE CROWD AND SHORE, PHOTOGRAPHED FROM THE DECK OF A COASTWISE SHIP.

tion of nearly four hundred species sent to the British Museum several years ago, nearly one in twenty-five proved to be new to science, yet the collector did not consider the series especially comprehensive. (One of the most interesting Siamese moths to the casual visitor is the giant Atlas moth so often figured in books on natural history. It is not infrequently seen in Bangkok.) The writer made a small collection of ants from various parts of Siam, and, although only "scratching the surface," this collection contained four forms new to science. Collections of a few other groups of insects have been made, but the insects in general are a closed book, and this statement applies in particular and with special interest to one of the largest and most widely distributed groups of insects, the beetles. It is remarkable that a group as large as this, and so spectacular in many ways, should have been practically neglected. Everywhere, in new countries, the spectacular seems to attract the collector's attention. The vertebrates and, among the invertebrates, the lepidoptera and coleoptera, usually come in for early attention. They are showy. Other groups are neglected almost in inverse ratio to their showiness.

A SPECIES OF *OCYPODE* AT ITS BURROW ENTRANCE
THIS FORM WAS COMMON ON THE BEACH AT HUA HIN.

The tourist at his first evening meal in Bangkok is made thoroughly aware of the wealth of insect life. A host of night-flying forms hover above the table, about the lights, or occasionally

MALAYAN TAPIR
THIS ANIMAL CONSTITUTED PART OF A SMALL ZOO MAINTAINED BY THE GOVERNOR OF SINGORA.

drop into his plate or drinking glass. These are almost ignored, however, for the bane of Bangkok in the evening is the mosquitoes. Malaria is rare in Bangkok, fortunately, though not elsewhere in Siam, but the capital seems to lead the country in mosquito as well as human population. The foreign residents protect their ankles with mosquito-boots, "mosquito-bags"—made of sarongs, splash themselves with some of the several anti-mosquito concoctions, or, better still, spend the evening in rooms which have been screened against mosquitoes. A comfortable evening in Bangkok is often only possible in one of the latter. One never thinks of sleeping outside a mosquito-net. Other insects are just as numerous, though not so annoying. Of special interest to the biologist are the aggressive, red tree-ants of the genus *Œcophylla,* which are everywhere. On one small pomelo tree in our compound there were a half-dozen large nests. Their exhibitions of muscularity in pulling together the leaves of the nest are marvelous, and, even among ants, it must be fairly novel to employ one's larvae as mucilage-tubes!

These are all free-living organisms. But there is another fauna, concealed, almost unknown the world over, about which still less is known in Siam. The parasites of a free-living fauna so little known are least known of all.

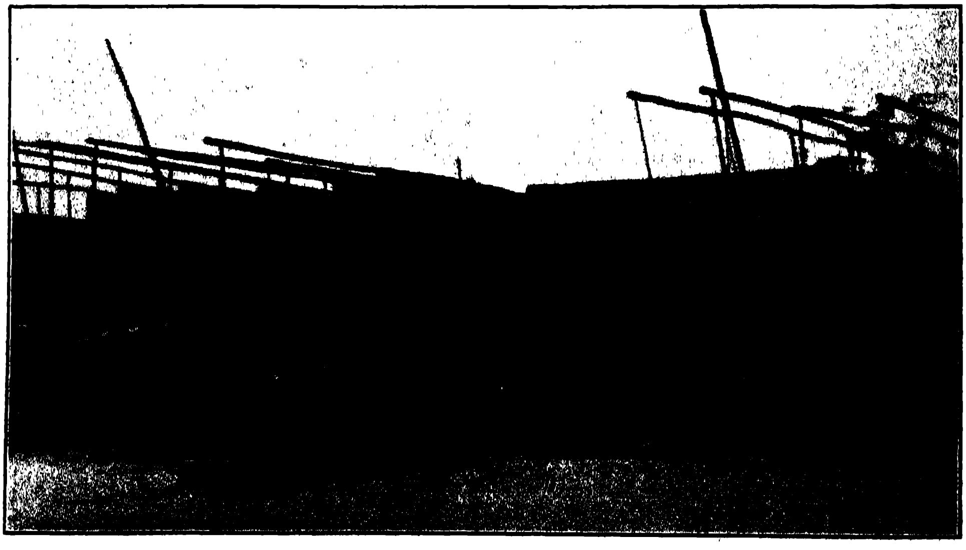
The vertebrates have received more attention. All groups have now been studied to a greater or lesser extent—the fishes by Dr. Hugh M. Smith, the amphibians and reptiles by Dr. Malcolm Smith, birds and mammals by eight or ten recent students. But even in groups as thoroughly investigated over a considerable period of time as have been the reptiles and birds, new species are still being discovered by the few collectors, and Dr. Hugh M. Smith assured me that he believed he would continue to find new species of fish every year as long as he remained in Siam. These new species are not necessarily rare species. Further than the taxonomic studies, a beginning has been made in studies of life histories, distribution, food habits, but in general the biology of Siamese vertebrates is little known.

The abundance of life, especially the number of varieties of organisms, is

A NEST OF *OECOPHYLLA*

FISHERMEN TAKING IN A NET

astonishing. The density of variation, if one may be permitted to use such an expression, is much greater in Siam than in the United States, in spite of the fact that our country shows greater climatic and topographic differences. Siam is entirely within the tropics, and temperature differences between different sections of the country are not great. No high mountain ranges act as effective barriers in definitely setting off particular zoological regions. Those



FISH NETS DRYING
AT PAKNAM, ON THE MENAM CHAO P'YA, BELOW BANGKOK.

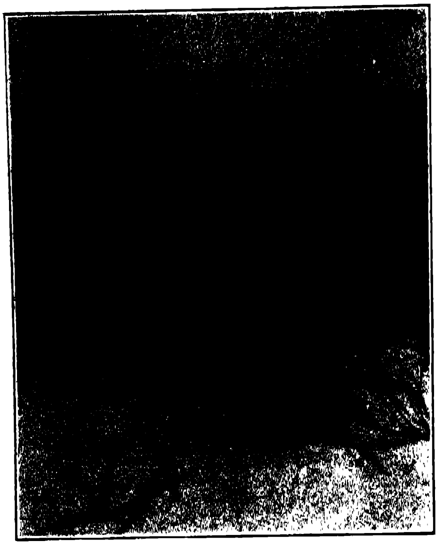
VULTURES AT A FEAST
THE SPECIES IS *Pseudogyps bengalensis* (*Gmel.*)

regions thus far postulated for Siam have merely been suggestive, and there is little to indicate that *marked* faunal or floral differences should exist between different regions within the country. Nevertheless, considering Siam as a whole, its variety of life is truly enormous.

In the *klongs*, or canals, of Bangkok there seems an inexhaustible supply of fishes. These are of many species. In a disused canal along one side of our compound, which had grown up heavily in water plants, rooted and floating, I collected a dozen species of fish in a space fifty feet long. The canal was some twelve feet wide and about two feet deep at the deepest. It is not unusual to see Siamese fishing with hook and line, and catching fish, in a canal that one can jump across; but, in spite of their continuous fishing, even with nets, the supply seems to keep up with the demand.

THE ROOT SYSTEM OF *PISTIA*

FISHERMAN WITH HIS CATCH
FROM THE INLAND SEA.



SPINIFEX

A DIOECIOUS GRASS, REMARKABLY ADAPTED FOR WIND DISSEMINATION, COMMON ON THE BEACH AT HUA HIN.

EICHHORNIA SPECIOSA KUNTH.

THE WATER HYACINTH, A NATIVE OF AMERICA, HAS BECOME SO ABUNDANT IN MANY RIVERS OF SOUTHERN ASIA AS TO BE A HINDRANCE TO NAVIGATION.

TRACKS IN THE MUD, MADE BY GOBIES

PISTIA STRATIOTES L.

THIS PLANT IS SAID TO BE MUCH LESS COMMON THAN FORMERLY, ITS PLACE BEING USURPED BY THE WATER HYACINTH.

NIPA FRUTICANS THUNB.

MAKING THATCH FROM LEAVES OF THE NIPA PALM

In area Siam is a little smaller than the state of Texas, but already the check-list of bird species from the kingdom is almost as long as that of the American Ornithologists' Union. It may prove to be longer. Already more genera and families of birds have been recorded from Siam than from North America north of Mexico. As striking evidence of the abundance of birds one might be referred to the report of de Schauensee's recent collections[4] made in northern Siam. In a period of about seven weeks (in December and January), with local collectors, he was able to secure representatives of over two hundred species. The collecting localities were hardly farther apart than New York and Philadelphia, and with a difference in elevation of but four thousand five hundred feet. Northern Siam and the neighboring countries constitute one of the most interesting sections of Asia for the ornithologist.

WINDOW SHOPPING IN HUA HIN

Such collections really indicate a rich bird fauna, and are not made up of a large percentage of rarities. The following results of a twenty-five minute morning bird census, taken from a moving train between Bangkok and Ratburi, serve to illustrate this fact. In this brief April census, 108 individuals were observed, representing at least twenty distinct species, of fifteen different families that could be readily recognized. Fifteen families of birds in

CASUARINA TREES AT SINGORA

THIS TREE IS PLANTED IN BANGKOK FOR ORNAMENTAL PURPOSES, BUT NOWHERE DID WE SEE IT SO WELL ESTABLISHED AS ON THE BEACH AT SINGORA.

A GOBY ON A MUD-FLAT

THIS INDIVIDUAL, WHICH WAS ABOUT EIGHT INCHES LONG, BELONGS TO A SPECIES OF *Periophthalmus.*

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[4] R. M. de Schauensee, "A Further Collection of Birds from Siam," Proc. Acad. Nat. Sci. Phila., 81: 523–588, 1929.

THE MENAM CHAO P'YA AT LOW TIDE
GOBIES ARE NUMEROUS ON SUCH MUDFLATS AS THIS.

twenty-five minutes of observation is certainly indicative of variety. In the same month, at Hua Hin, in peninsular Siam, Mrs. Alexander and I recorded over forty species of birds in a walk from six to eleven A. M. Such a list can not be compared with an April list in New Jersey, which should be much longer, of course, but April in Siam is the hottest and driest month of the year. Hence, in this short trip on foot, we observed over forty presumably resident species.

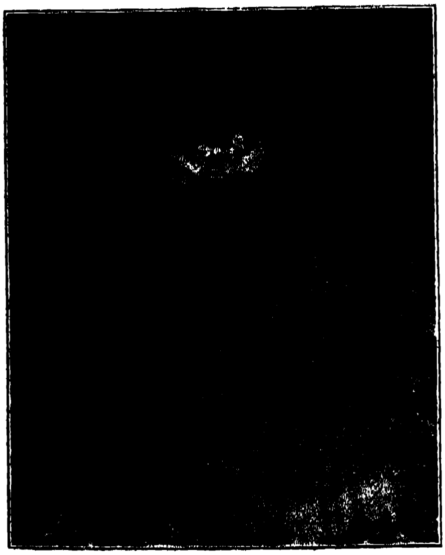
Certain groups of animals, which seem to illustrate definite evolutionary trends, are of special interest. The vertebrates, other than birds, that have essayed flight are well represented. In the Gulf are flying fishes; in the cocoanut groves occur several species of the "flying dragon," *Draco,* and also *Ptychozoon,* the gecko which probably does not fly—contrary to early opinion. The former has excited interest from the earliest reports of its existence. I have seen a fair representation of it in a book published as early as 1686.[5] Flying squirrels of several species, some quite large, occur, as also the large insectivore, the so-called flying lemur. Bats, both frugivorous and insectivorous, are abundant. "Flying foxes," of the genus *Pteropus,* are very common.

A similar behavior group is constituted by the fishes that show various adaptations toward air-breathing. These vary in "success" from a type like *Trichogaster,* which has an accessory breathing organ, but is so flattened laterally that it is incapable of progressing out of water, through *Clarias, Ophiocephalus,* and the so-called climbing perch to the beach-skipping gobies.

[5] O. Jacobaeus, "O. Jacobaei de Ranis et Lacertis observationes." Hafniae. [xiv] + 144 pp., 1686.

The latter remain out of water for long periods, and actively and swiftly move along the mud-flats, pulling themselves by the pectoral fins. Altogether about twenty species, perhaps more, of fish variously modified for air breathing are found in the canals and the river near Bangkok. During May and June, 1930, Dr. A. S. Pearse studied these types in Bangkok with reference to the general problem of the migration of organisms from sea and fresh water to land. The results of his studies will indicate in part the opportunity in Siam for observation on what still remains the greatest problem in biology—the origin of adaptation, the origin of species.

With the flora as with the fauna, the striking forms have received the chief attention. The cryptogams have been largely neglected. But even with the flowering plants, the botanist's task is a long one. Dr. A. F. G. Kerr, who has collected plants more extensively in Siam than, perhaps, any other individual, estimates the flowering plants of Siam at 10,000 species. The Florae Siamensis Enumeratio of Craib, now appearing in parts, as issued by the Siam Society, will summarize the present knowledge of Siamese flowering plants. Of the species thus far collected, about 20 per cent. are endemic. Wherever foreign contact has come, foreign types have been introduced. In Bangkok nearly 30 per cent. of the flora is introduced; and it is interesting that tropical America, including the West Indies, has supplied more than one third of the introduced species. The problem of the flora is no easier than that of the fauna, and offers a long future of useful study. If we should attempt to summarize in broad fashion the present position of the biology of Siam we should be compelled to say that a very small fraction of the fauna and flora is known even by name, and that little but little more than by name.



NELUMBIUM SPECIOSUM WILLD.
THE SACRED LOTUS IS WIDELY CULTIVATED IN SIAM.

RAIN FOREST ON KOH CHANG
THIS ISLAND, IN THE EASTERN PART OF THE GULF OF SIAM, IS IN ONE OF THE HEAVY RAIN BELTS.

The country itself, though ranging

THE PLOUGHING CEREMONY
A ROYAL CEREMONY AT BANGKOK INITIATES THE RICE-PLANTING SEASON.

through sixteen degrees of latitude, does not show a wide variation in temperature. There is, however, considerable variation in rainfall between different sections, largely due to the location of mountain ranges in relation to moisture-laden winds. Most of the rain comes from the southwest. The heaviest rainfall, therefore, is along Siam's portion of the west coast of the peninsula. The mountains along the boundary between Burma and Siam are such an effective barrier that the rainfall on their western slopes is three times as heavy as that which reaches the plains of central Siam. Another region of heavy rainfall lies along the east coast of the Gulf of Siam. Here also, as along the west coast of

REMOVING RICE PLANTS FROM THE SEED PLOT
THREE OF THE PLOTS IN THE BACKGROUND HAVE BEEN SET OUT, WHILE ONE IS READY FOR THE SEEDLINGS.

ELEPHANT ROLLING TEAK LOGS INTO THE YOM RIVER

peninsular Siam, one finds the so-called tropical rain forest, a rather heavy evergreen forest in which epiphytes and climbing plants are especially abundant. But, although most of the rest of Siam is forested, none of this area is so luxurious, and much of it is open and deciduous. Over most of Siam there prevails alternate rainy and dry seasons, and the annual rainfall may be only forty or fifty inches; in fact, in some sections it is less even than that. It is, then, manifestly incorrect to indicate heavy rain forest all over Siam in phytogeographical maps. Further, a considerable area is unforested. Most of the plain of the Menam Chao P'ya, the great central river of Siam, is an unforested rice plain. Siam is more than half forested, but only small sections of this are as heavily forested as much of Burma to the west or Malaya to the south.

The Siamese people are agricultural. Since they first began to filter into their present territory from the north, a thousand years ago, they have concentrated themselves in the broad river plains which could best be adapted to rice culture. In the north, where the land is mostly hilly, these rice plains are rather accurately defined. In each such plain, between the more or less parallel, north-and-south ranges of hills, are concentrations of people, *e.g.*, at Chiengmai, Lampang and Nan. But, naturally, the greatest concentration of population to-day is in the valley of the Menam Chao P'ya. (Menam is Siamese for "river"; which means that the usual map designation, ***Menam River***, is ambiguous.) The plain of this river extends north from the mouth two hundred miles, varying in width from forty to one hundred miles. The delta proper is nearly a hundred miles long. Bangkok, with other lesser cities, is located in the delta. The rice growers around Bangkok are almost as dependent on the annual inundations of the Chao P'ya as are the Egyptians on the overflow of the Nile. Artificial irrigation is known and widely practiced, but the chief advantage of the annual overflow is, apparently, in the renewing of the soil, obviating the necessity of fertilizing.

Agriculture furnishes the key to the chief expansion of biology in Siam, but the possibility of scientific improvement of agriculture has really not become a

TEAK LOGS IN THE MENAM YOM AT PRAE

AT THIS TIME LOGS WERE BEING COLLECTED IN THE RIVER AWAITING FLOOD WATER.

part of the "social consciousness." The division of the government concerned with agriculture should be one of its strongest departments. Actually, it is one of the weakest. Only in the Department of Fisheries, through the organizing activity of Dr. Hugh M. Smith, has any considerable progress been made. This is not insignificant, however, as, next to rice, fish constitutes the most important element of the Siamese diet. The value of the annual catch has been estimated at twenty-five million ticals,[6] or about twelve million dollars; and only about 12 to 15 per cent. of this catch is exported. Forestry conservation, representing a third field for the application of biology, has been practiced for some time, though limited to the more valuable timbers, *e.g.*, teak. Proper integration of these three fields of official effort and the department of biology of Chulalongkorn University (the only university in Siam) will increase enormously the field of service of the latter, and improve the efficiency of the former.

At present, biology instruction in Siam is practically limited to pre-medical students. Largely through the cooperation of the Rockefeller Foundation in pre-medical education, in connection with the medical program, the departments of biology, chemistry and physics have been firmly established. Training in the latter two sciences is required of engineering students, but training men locally for the fisheries, forestry and agriculture has not been practiced—at least of those men who are expected to have positions of governmental responsibility. Local training of men for the fisheries has, however, been suggested. There is a move on foot now, following the natural evolution of the university, to provide for four years' instruction in biology. The present pre-medical curriculum is for only two years. The benefits of such a plan must necessarily involve the correlation of various fields of applied biology in the educational system. But more than that, it should mean the establishment of a nucleus of Siamese investigators who can exploit properly the scientific as well as economic resources of the fauna and flora of their country. Only then can the biological opportunities of Siam be fully realized.

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[6] H. M. Smith, *Ibid.*

DEVELOPMENT OF THE EGG FROM THE STANDPOINT OF THE GENETICIST[1]

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DEPARTMENT OF GENETICS, CARNEGIE INSTITUTION OF WASHINGTON, COLD SPRING HARBOR, N. Y.

IN the two preceding papers of this series[2] the development of the egg has been considered from the standpoint of the embryologist and the physiologist, respectively, in accounts which dealt especially with the human egg or with the eggs of mammals closely related to man, and stressed particularly those aspects which obviously have direct bearing on human development. In the present account attention is invited to another aspect of development, or rather to some more general aspects of development. At first sight many of the features discussed here may seem to have little relation to man, but in the long run they will, I believe, lead to conclusions bearing as directly on human development as on that of the other animals whose characteristics or behavior they reflect.

Like most other fields of biology, the study of development requires experiments; and since man is one of the most unsatisfactory animals for experimental purposes students concerned with the fundamental aspects of development, without special regard for immediate human problems, have avoided man for the most part and have confined their attention to the lower animals. It is studies in this latter field which I wish particularly to consider.

If we look back about thirty-five years in the history of biology we find that the development of the egg, considered from this general point of view, was receiving the concentrated attention of many of the leading biologists of the world. The work of these men marks an epoch in biological advance, and we can do no better, I believe, in approaching the subject of development than to begin with a consideration of their period.

The actual studies carried on at this time involved eggs of all sorts, from the minute free eggs of the sea-urchin and starfish to the large enclosed eggs of the frog and chick. These eggs were observed as they developed under ordinary normal conditions, and observed as they developed under various unusual or artificial conditions, such as followed, for instance, from treatment with heat, cold, various chemical agents, pressure, radiation, etc. They were also cut up into fragments and the behavior of the fragments studied, and they were whirled rapidly in the centrifuge to force their internal components into different relations to one another, to see what effect this would have on development. In fact a multitude of different experiments were carried out.

The purpose of all these was not simply to see in what manner the eggs developed. That could be determined by direct observation in most cases. It was to learn *why* the different kinds of eggs developed as they did; why one kind of egg developed in a particular way and gave rise to one kind of animal, while another kind of egg under the same conditions developed in a different way and gave rise to another kind of animal.

More specifically the design was to find out two things: first, what it is in the egg which controls the developmental processes, and second, how this agency functions. In other words, is it

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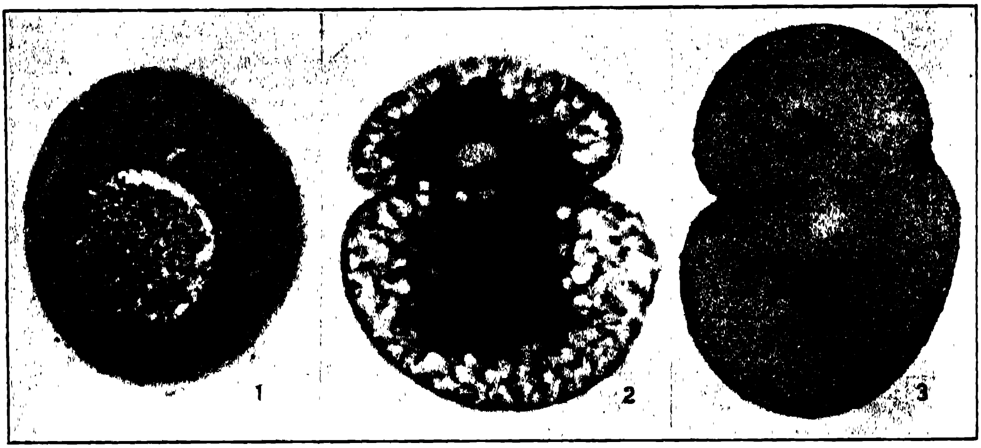
[1] From a symposium on development given at the Carnegie Institution in Washington in November, 1930.

[2] See papers by Dr. Streeter and by Dr. Hartman in the two preceding numbers of this journal.



FIGS. 1–3. PHOTOGRAPHS OF SINGLE AND DIVIDING EGGS.[3]
FIG. 1. STARFISH EGG BEFORE DIVISION. FIG. 2. EGG OF THE MARINE WORM, *Nereis*, AFTER THE FIRST CLEAVAGE. FIG. 3. WHITEFISH EGG, TWO CELL STAGE, IN PREPARATION FOR SECOND CLEAVAGE. FIGURES ALL FROM FIXED AND SECTIONED MATERIAL.

a general property of the whole egg which determines how that egg is going to develop and what it is going to become; or is this determining function limited primarily to a certain part, or parts, and in either case what is the method of procedure involved?

Space will not permit going into the details of the various experiments carried out during this period, but we may note a few general features which stand out prominently in the work. In the first place it immediately became clear, if it was not already so, that the egg of each different kind of animal has certain definite potentialities. For example, a frog's egg produces a frog—and a frog of a certain definite species—nothing else. The egg may be injured so it will not develop, or it may be made to develop into a deformed or abnormal frog, but, no matter how it is treated, what it finally becomes must lie within the definite range of potentialities inherent in the egg before development began.

Thus the first question to be answered was: what is it in the egg which determines these potentialities? In considering this question we must turn attention to some of the actual processes of development. Ordinarily these involve two separate things: on the one hand, the *growth* of the embryo, and on the other hand, its *differentiation* into different parts. It is through these two processes that the small and relatively simple egg becomes the large and relatively complex animal.

The first step in development is the division of the egg. To begin with, the egg is a single cell, as seen in the accompanying photograph of a starfish egg (Fig. 1). Then it divides into two cells (Figs. 2 and 3) as Dr. Streeter pointed out in the first article of this series, and these in turn into four, and so on until, in most cases, millions of cells are present. Each of these cells has a definite structure—a structure which follows a common general plan in practically all cases, not only within one animal, but throughout the whole animal and plant kingdoms. The superficial features of this plan are shown in the accompanying photograph of living cells (Fig. 4) taken with the aid of ultra-violet light, which reveals the structures better than does visible light. For this and the other ultra-violet photograph used here (Fig. 15) I am indebted to Mr. F. F. Lucas, of the Bell Telephone Research Laboratories.

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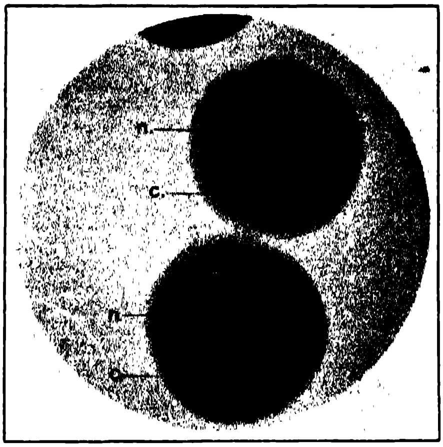
[3] Photographs not otherwise accredited are original.



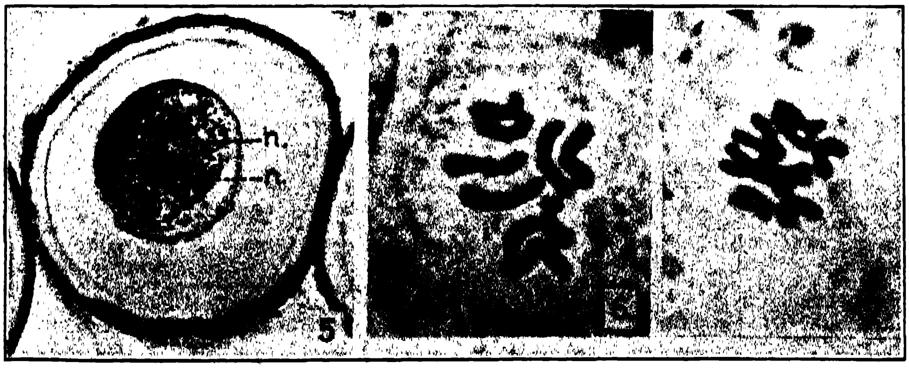
—Courtesy of Mr. F. F. Lucas.

FIG. 4. ULTRA-VIOLET PHOTOGRAPH OF LIVING CELLS OF GRASSHOPPER. *n*, NUCLEUS; *c*, CYTOPLASM.

The two most conspicuous regions of the cell are the nucleus (n) seen near the center, and the material surrounding it (called the cytoplasm) which goes to make up the rest of the cell. Both the nucleus and the cytoplasm, in turn, contain other differentiated structures, but for the moment these may be left out of account.

One of the first results of the experiments under consideration was the demonstration that the nucleus is essential for development. It was found that when an egg cell was cut in two, leaving the nucleus in one half, that half could develop into an embryo, but the half lacking a nucleus could not. Even if the nucleus was cut off almost alone, as could be done in some cases, leaving the egg nearly entire, still the egg would not develop without the nucleus. From such experiments it was concluded that development must be greatly influenced by something in the nucleus.

This conclusion, in turn, led to additional experiments; and in considering these it is necessary to go still further back in the life of the egg to the process which, in most animals, really initiates development—that is, the fertilization of the egg by the sperm. The study of the sperm and of fertilization soon revealed another fact of special significance, namely, that the sperm, or the part of it which enters the egg and takes part in later development, is extremely small, as compared with the egg, and apparently consists mainly of nucleus. This obser-



FIGS. 5–7. PHOTOGRAPHS OF NUCLEI AND CHROMOSOMES FROM FIXED AND STAINED PREPARATIONS.

FIG. 5. EGG OF A THREAD WORM, *Ascaris megalocephala* VAR. *univalens*, SHOWING THE EGG NUCLEUS (n) AND SPERM NUCLEUS (n) UNITING AT FERTILIZATION. EACH CONTAINS A SINGLE LONG CHROMOSOME. FIG. 6. CHROMOSOMES OF THE ROBBER FLY, *Dasyllis*, FROM A SPERMATOGONIAL CELL. THE SINGLE SMALL CHROMOSOME IS THE UNPAIRED SEX CHROMOSOME. FIG. 7. CHROMOSOMES OF THE COMMON HOUSE FLY, *Musca domestica*, FROM AN OVARIAN CELL.

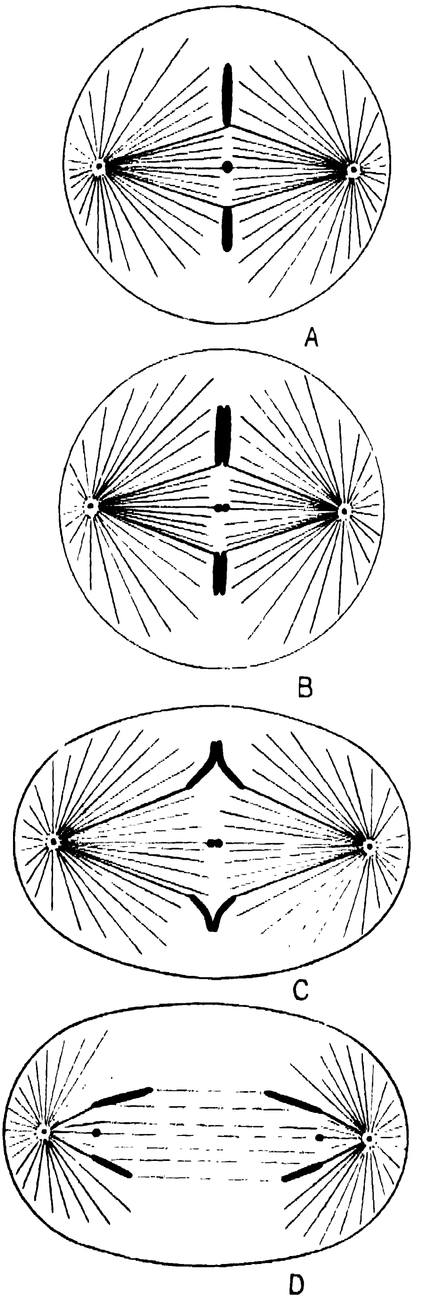


FIG. 8. DIAGRAMS OF CELL DIVISION, OR MITOSIS, SHOWING MOVEMENT OF THE CHROMOSOMES.

A. Metaphase, before the division of the chromosomes is evident. (Actually division occurs before this stage, but it is not always evident.) *B*. Later metaphase showing duality of the chromosomes. *C*. Early anaphase, showing separation of the daughter halves. *D*. Late anaphase, after daughter halves have passed toward the poles.

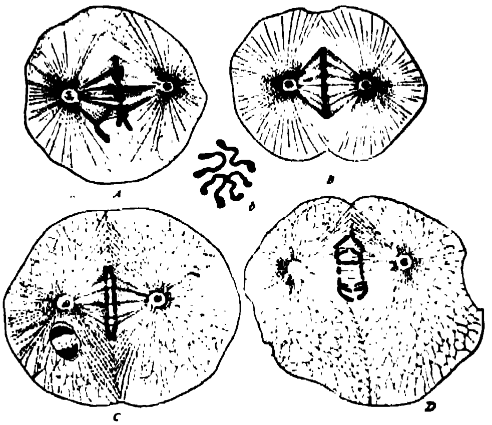


FIG. 9. MITOSIS IN A THREAD WORM, *Ascaris megalocephala* var. *bivalens*. Drawings from fixed and sectioned eggs, showing the amphiaster. *A–D*. Side views. *b*. Chromosome group in polar view. (From Wilson after Boveri).

vation proved fruitful in two directions: In the first place it led to the experiment of fertilizing the half of a cut egg which had no nucleus, and thereby introducing a nucleus into something which was known to be incapable of development alone. When so fertilized, it was found that such fragments could develop, indicating that the sperm brought in the essential elements. And in the second place, it suggested a comparison of the respective influences of the male and the female parent on the characteristics of the offspring, on the principle that if the nucleus contained the important elements the male ought to have just as great an influence as the female in spite of the small size of the sperm. As will be indicated a little later, it was found that in general the male actually does have an influence equivalent to that of the female.[4]

Such considerations as these led eventually to the focussing of attention specifically on the nucleus, and to extensive

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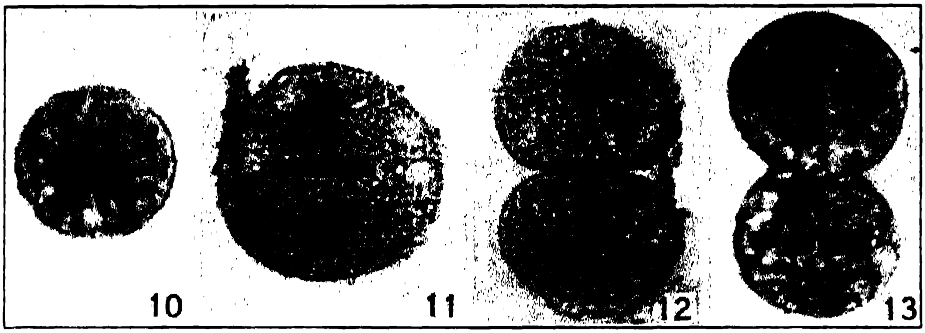
[4] Although extremely minute at first, the sperm head swells after entering the egg and eventually gives rise to a nucleus similar in size and constitution to that of the egg, as shown in Fig. 5. Fertilization is completed by the fusion of these nuclei.



FIGS. 10–13. PHOTOGRAPHS OF MITOSIS IN EGGS OF A THREAD WORM.
FIG. 10. FIRST CLEAVAGE DIVISION OF EGG; POLAR VIEW OF METAPHASE. (COMPARE WITH FIG. 9*b*.) FIG. 11. SAME STAGE IN SIDE VIEW SHOWING THE AMPHIASTER. FIG. 12. LATE ANAPHASE, CELL ALMOST COMPLETELY DIVIDED. FIG. 13. METAPHASE OF SECOND CLEAVAGE DIVISION SHOWING AMPHIASTERS IN SIDE VIEW, ORIENTED IN CHARACTERISTIC MANNER (FOR THIS EGG) AT RIGHT ANGLES TO ONE ANOTHER. NOT ALL CHROMOSOMES ARE IN VIEW IN FIGS. 11–13. ALL FIGURES FROM FIXED AND SECTIONED MATERIAL.

studies on its organization and behavior. Many observations had, of course, already been made in this field, and we can not attempt here to retain an exact chronological order in considering the subject. But the first feature of importance for our purpose which came out of the early studies was the demonstration that just as the nucleus is the most significant or prominent structure in the cell, so the most significant components of the nucleus are the bodies called chromosomes (the dark bodies shown in Fig. 6).

Indeed it soon became apparent that in many cases the nucleus is actually derived from the chromosomes, so that in general the chromosomes may be considered as representing the nucleus. In consequence, attention was diverted to a direct consideration of the chromosomes themselves.

This shift in attention led to a series of brilliant experiments by Boveri which in some respects marked the climax of the period under consideration. The material used for his experiments was the sea-urchin. Boveri found that he could fertilize the eggs of some species of sea-urchins with sperms from other species which developed in a different way, and then could trace the influence of each parent on the development of the hybrid embryo. And he found that

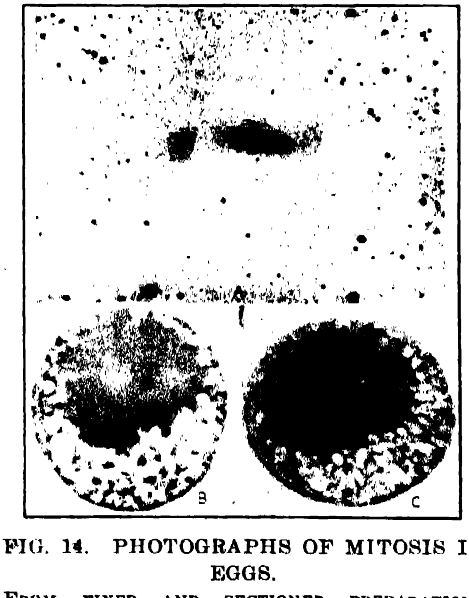
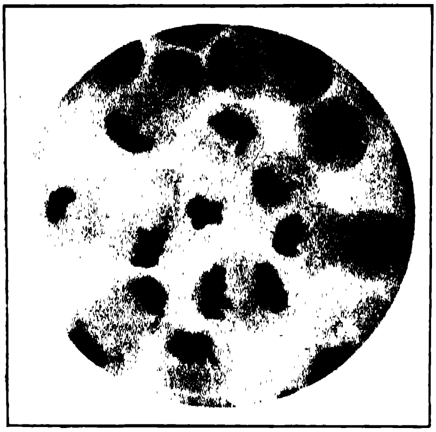


FIG. 14. PHOTOGRAPHS OF MITOSIS IN EGGS.
FROM FIXED AND SECTIONED PREPARATIONS SHOWING AMPHIASTER IN SIDE VIEW. *A*. SECOND CLEAVAGE OF WHITEFISH EGG (ENLARGED FROM FIG. 3 SHOWN ABOVE). *B*. MARINE WORM, *Nereis*, METAPHASE OF FIRST CLEAVAGE SHOWING LARGE ASTERS AND LONG ASTRAL RADIATIONS IN CYTOPLASM. *C*. SAME, ANAPHASE, SHOWING SEPARATION OF DAUGHTER CHROMOSOMES.



Courtesy of Mr. F. F. Lucas.

FIG. 15. PHOTOGRAPH OF LIVING GRASSHOPPER CELLS TAKEN WITH ULTRA-VIOLET LIGHT.

LATE STAGES OF MITOSIS, SHOWING CHROMOSOMES PASSING TO THE POLES (OPPOSITE SIDES OF THE CELL) OR AFTER THEY HAVE ARRIVED AT THE POLES AND THE CELL HAS DIVIDED OR BEGUN TO DIVIDE.

development in these hybrids was not always the same; sometimes the embryo would develop in a fashion intermediate between that of the two parents, while in other cases it would develop just like normal embryos of the species from which the *mother* came. That is, in this latter case the sperm seemed to have no effect.

At first these results presented a puzzling mystery; but later the key to the solution was found in the fact that the peculiar differences in behavior were apparently due to corresponding differences in the behavior of the chromosomes in the various cases. In cases of the first type, for example, both the sperm chromosomes and egg chromosomes took part in development, hence the embryo was intermediate between the two parents, while in the second class of cases the sperm chromosomes degenerated and

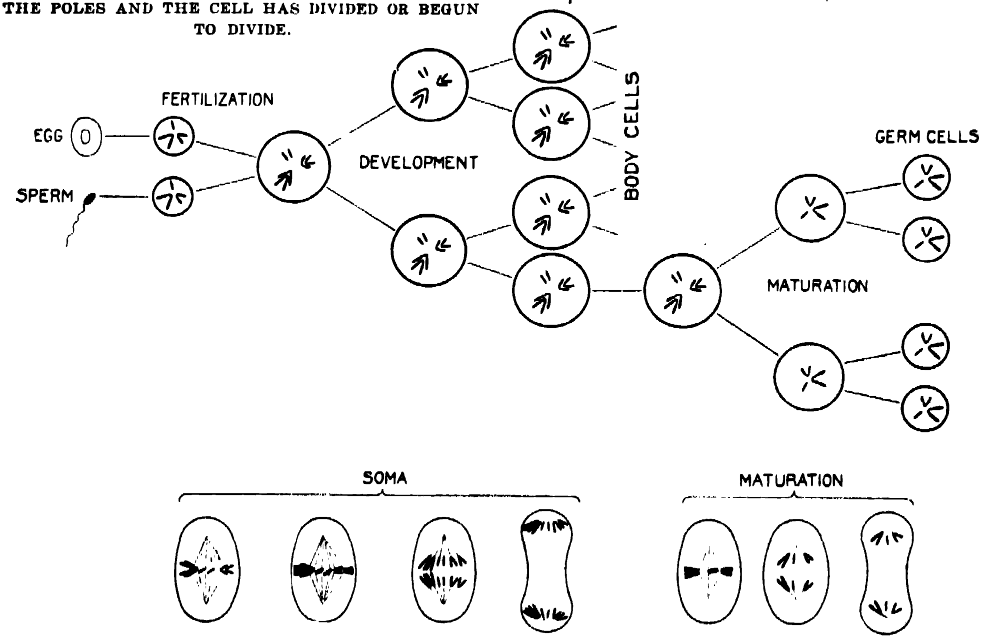
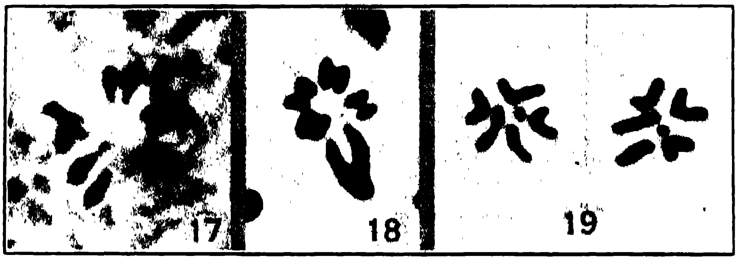


FIG. 16. DIAGRAM ILLUSTRATING THE HISTORY OF THE CHROMOSOMES DURING THE LIFE CYCLE OF AN ANIMAL.

ABOVE: EGG AND SPERM UNITE AT FERTILIZATION. EACH CONTAINS THREE CHROMOSOMES (IN THIS PARTICULAR SPECIES OF FRUIT FLY), AND HENCE CONTRIBUTES EQUALLY TO THE CHROMOSOMES OF THE OFFSPRING. THE CHROMOSOME GROUP IS PERPETUATED DURING DEVELOPMENT BY MEANS OF ORDINARY MITOSIS. WHEN THE GERM CELLS ARE FORMED, HOWEVER, THE NUMBER OF CHROMOSOMES IS ACCURATELY REDUCED BY A SPECIAL MITOSIS DURING "MATURATION" WHICH BRINGS ABOUT A SEPARATION OF CORRESPONDING CHROMOSOMES. BELOW: THE TWO TYPES OF MITOSIS SEEN IN SIDE VIEW.



FIGS. 17–19. PHOTOGRAPHS OF CHROMOSOME GROUPS IN FLIES, SHOWING DIFFERENCES IN NUMBER, SIZE AND FORM OF CHROMOSOMES.

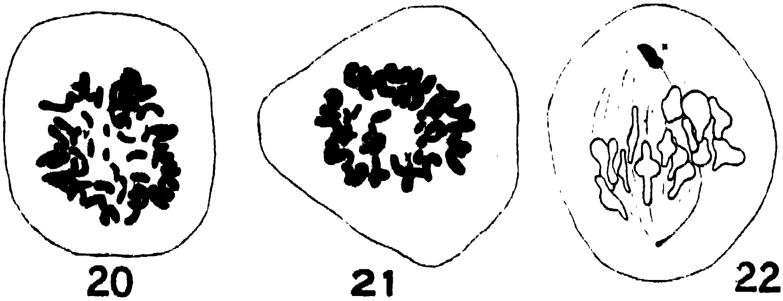
Fig. 17. The five rod-like pairs in a body cell of the fruit fly *Drosophila virilis*. Fig. 18. Similar view of chromosome group in another fruit fly, *Drosophila funebris*, showing four short rod-like pairs, one long rod-like pair (below) and one extremely small dot-like pair (in center, the members not very close together). Fig. 19. Two germ cell groups in a blow fly, after the chromosome number has been reduced at maturation. Six chromosomes in each group, including two rod-like, one dot-like and three V-shaped members. At fertilization two such groups are brought together, giving a group similar to that shown in Fig. 7, except for size relations.

did not take part in development, hence the embryo developed like its mother.

Thus, as far as could be observed, development seemed to be dependent on the chromosomes, without any clear relation to other constituents. In addition to this, it was being shown by other investigators at the same time that attempts to correlate development with other visible materials in the egg led to a variety of conflicting results which could only be harmonized on the assumption that these other materials played a secondary rôle.

So the upshot of the work of this whole period as regards the present subject was that nothing in the cell appeared consistently to bear any such relation to development as did the chromosomes. Much was thus accomplished by centering attention on the chromosomes, but it seemed impossible to go beyond this and get direct evidence as to *how* or *why* the chromosomes performed their unique function. The investigators, as one of them expressed it, were "confronted by a stone wall."

Looking back on that period now it is not difficult to see that the obstacle to further progress consisted in large measure of two things: First an insufficient knowledge of the chromosomes themselves—their structure, behavior, constancy, etc.—and second an insufficient



FIGS. 20–22. CHROMOSOMES OF MAN. *After Painter.*

Figs. 20 and 21. Polar view showing entire chromosome group, as found in body cells and spermatogonia (germ cells of male before maturation). Fig. 22. Maturation division in male showing separation of the two sex chromosomes (large X and small Y).

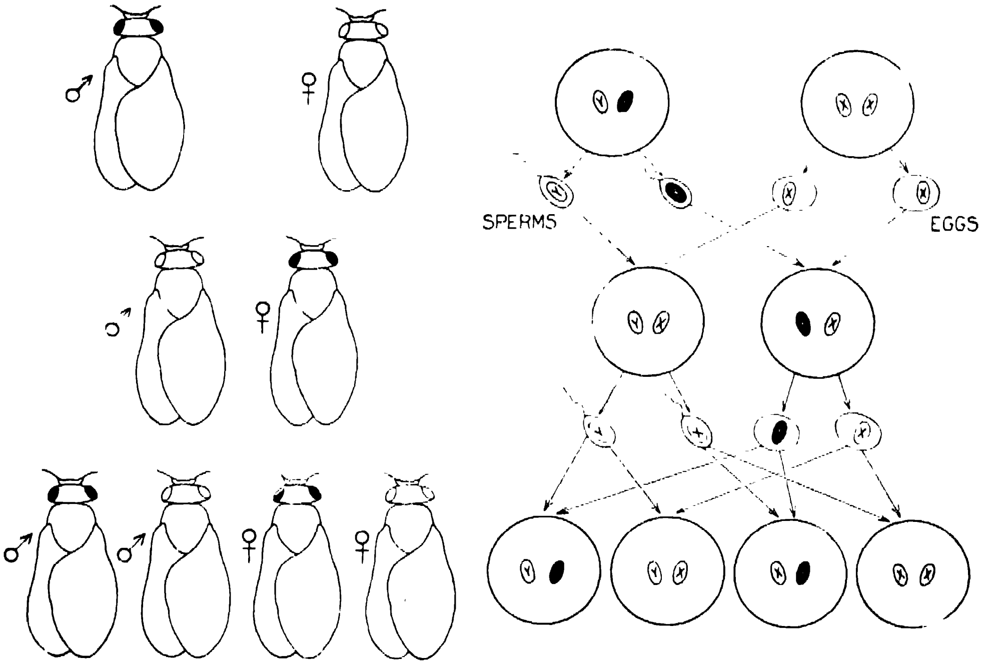


FIG. 23. DIAGRAM ILLUSTRATING SEX-LINKED INHERITANCE IN THE FRUIT FLY *Drosophila*. *From Sharp, after Morgan.*

♂, MALE; ♀, FEMALE; X-CHROMOSOME INDICATED BY X; Y-CHROMOSOME BY Y; RED EYES REPRESENTED IN BLACK; WHITE EYES IN OUTLINE. THE X-CHROMOSOME CARRYING THE GENE FOR RED EYE COLOR IS REPRESENTED IN BLACK. SINCE THIS GENE IS "DOMINANT" ANY FLY RECEIVING IT HAS RED EYES. SINCE THE X-CHROMOSOME OF THE MALE ALWAYS PASSES TO DAUGHTERS, AND THE Y (WHICH DOES NOT CARRY THE GENES UNDER CONSIDERATION) PASSES TO SONS, "CRISS CROSS" INHERITANCE RESULTS IN THE FIRST GENERATION—THE DAUGHTERS BEING LIKE THE FATHER AND THE SONS LIKE THE MOTHER.

knowledge of heredity, or what is now known as the field of genetics, particularly that part of genetics which shows the relation between the chromosomes and heredity. For studies on these subjects a different method was required.

Hence it is no mere coincidence that the intensive study of chromosomes under the microscope, and the study of heredity (*i.e.*, genetics) entered their most productive period just as these activities in experimental embryology subsided. In both of the new fields just mentioned there has been great activity for the past twenty years or more—an activity resulting in a detailed knowledge of chromosomes and of heredity which is not only significant on its own account, but which has thrown a new light on development, and has also, it seems to me, made it possible now to attack the problems of development in a new fashion and with a new tool.

It is for this reason, therefore, that in considering development from the standpoint of the geneticist I would invite attention particularly to the correlated results of studies on chromosomes and on heredity. The limitations of space necessitate making such a review very brief, hence it will be necessary to omit many features entirely and pass over others with only a few words. What I hope to do specifically is to give a brief picture of what the chromosomes are and how they behave, and then to indicate

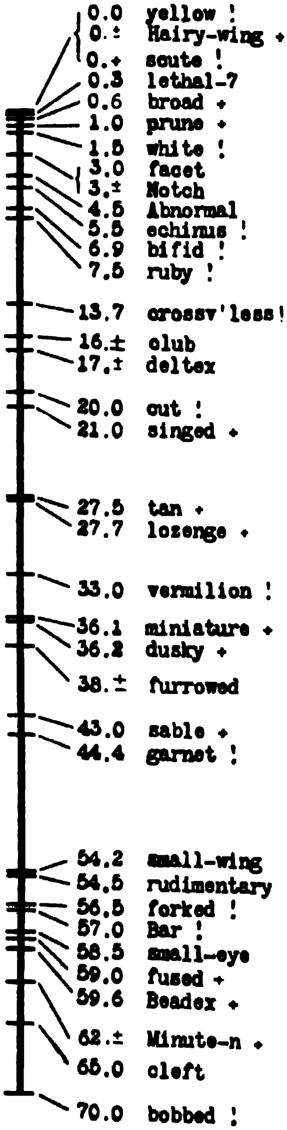


FIG. 24. "MAP" OF THE X-CHROMOSOME IN THE FRUIT FLY *Drosophila melanogaster*. *After Morgan, Bridges and Sturtevant.*

CROSS LINES REPRESENT THE RELATIVE "POSITIONS" OF THE GENES RESPONSIBLE FOR THE CHARACTERS INDICATED AT THE RIGHT.

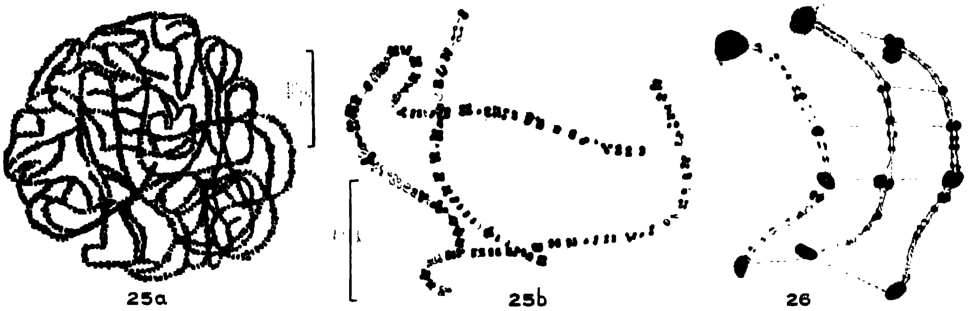
the rôle they play in heredity and the relation which they must, on that account, bear to development.

In doing this let me recall the fact brought out by Dr. Streeter in the first article of this series, that the development of the egg is not completed until the animal has become fully grown and mature. Consequently, we are as much concerned with processes occurring in the embryo or individual after it has passed the so-called "egg stage" as with those transpiring during this stage.

When viewed under the microscope in prepared specimens the chromosomes appear about as shown in the accompanying photograph of a cell of one of the robber flies (Fig. 6). In this particular case the chromosomes are of different shapes and sizes. Each body cell in the whole animal has this same set of chromosomes. To give some idea of the minute size of these structures it may be observed that the entire field shown in the photograph is far below the limit of vision with the naked eye. Another illustration is seen in Fig. 7, from a similar photograph of the chromosomes of the common house fly, which has a somewhat different group of chromosomes.

In both of these photographs the chromosomes have been shown at the time the cell is about ready to divide, which is the stage at which the chromosomes are most compact and the only stage at which they are arranged in one plane in such a way that they may all be photographed at once. At other times they move about in the nucleus and change their shape and consistency. Also when the cell is about to divide the nuclear membrane breaks down leaving the chromosomes lying free in the cell. For present purposes, however, we may disregard these changes in form, etc. (which apparently have to do with the physiological activity of the chromosomes) and think of the chromosomes as shown in the figures.

If we trace the history of any cell during development—either the egg cell, or one of the cells descended from it—we find that when the cell divides to



FIGS. 25 AND 26. DETAILS OF CHROMOSOME STRUCTURE.
25 *a* AND *b*, LOW AND HIGH MAGNIFICATION, RESPECTIVELY, OF CHROMOSOME PAIRS IN A LILY (AFTER BELLING). FIG. 26. GRASSHOPPER CHROMOSOMES (AFTER WENRICH). THREE DRAWINGS REPRESENTING ONE PARTICULAR PAIR OF CHROMOSOMES AS SEEN IN THREE DIFFERENT CELLS, SHOWING THE CONSTANCY OF THE STRUCTURAL ORGANIZATION OF THE CHROMOSOME. THESE FIGURES REPRESENT THE STAGE AT MATURATION DURING WHICH THE TWO HOMOLOGOUS CHROMOSOMES ARE INTIMATELY ASSOCIATED. NOTE THE CORRESPONDENCE IN STRUCTURE OF HOMOLOGUES IN BOTH FIG. 25 AND FIG. 26.

make two daughter cells the chromosomes also divide, so that each daughter cell receives half of each chromosome, thus keeping the chromosome group constant in all the cells (save for certain special cases to be considered later). This process is shown diagrammatically in Fig. 8. At first the chromosomes become arranged in one plane in the center of the cell, then each one divides lengthwise in a precise fashion, and the two daughter halves go to opposite sides of the cell. After this is accomplished the cell divides and each daughter cell has the full set of chromosomes, each chromosome being a replica of its ancestor.

The actual processes taking place here are very delicate and accurate, and in the cells as seen under the microscope at this stage there is a beautiful, bipolar structure called the "amphiaster" which apparently represents the mechanism responsible for the distribution of the chromosomes. This structure is shown better in the accompanying drawings of the dividing egg of one of the parasitic thread worms (Fig. 9). Here the astral structures are especially clear, with rays running out into the cell, and also with rays extending to the chromosomes, making the so-called "spindle fibers" which look as if they were actually pulling the halves of the chromosomes to the two poles of the figure (as shown in B, C and D). The latter drawings represent side views. When viewed from one pole the chromosomes appear as shown in (b)—this species having four long, V-shaped chromosomes. Photographs of such stages taken directly from the eggs after they have been fixed and stained for study are shown in Figs. 10 to 12. The first represents the chromosome group as seen from one pole; the second represents the same stage in side view, showing the chromosomes at the equator of the figure as the cell is preparing to divide, and the third shows the chromosomes after they have divided and are part way toward the poles of the figure (not all chromosomes in view here). And finally, in Fig. 13 is shown a later stage, after division has been completed and the two daughter cells are getting ready to divide again.

Another series of mitotic figures is shown in Fig. 14. These photographs are from material especially favorable for study of the astral and spindle structures rather than the chromosomes. The first is a more highly magnified view of the amphiaster shown in Fig. 3, from the whitefish. The other two represent stages in the first cleavage of eggs of the marine worm, *Nereis*, preceding the two-cell stage shown in Fig. 2.

The preceding photographs all represent conditions as seen in prepared material, and it may be of interest to note that, so far as the chromosomes are concerned, the essential features are also visible in the living cells. It is even possible to show them in photographs of living cells with the aid of ultra-violet light, as indicated by the accompanying photograph of cell division in one of the grasshoppers, taken by Mr. Lucas (Fig. 15). In this material the chromosomes are too numerous and crowded to be shown individually at such stages, but the essential characteristics are entirely clear. The stages represented in the photograph are relatively late, after the chromosomes have arrived at the poles and the cells are dividing or about to divide.

We see, then, that the cell has a highly specialized, delicate mechanism which insures the accurate division and distribution of the chromosomes at each cell division, so that as the organism develops each cell gets the exact set of chromosomes with which the fertilized egg began its development. In other words, organisms have, somehow, during the course of evolution, developed a method which insures the perpetuation of the chromosome group from cell to cell.

It is a remarkable fact that this process is essentially universal in all animals and plants. We must assume, therefore, since it involves such a complicated and delicate procedure, that it has a special general significance, and that the bodies which are so accurately divided and distributed must be of special importance.

This fact has long been appreciated. Indeed it was recognized during the period of embryological activity just considered, and it was one of the experimental embryologists, Roux, who first pointed out the possible significance of the processes. According to Roux this accurate longitudinal division of the chromosomes and the precise distribution of the daughter halves could only be understood on the assumption that each chromosome is a composite of different materials, presumably different chemicals, which are arranged in series along the length of the chromosome and are divided so that each one is handed on to the daughter cells at each division. Also, on his view, such a process would be meaningless unless these different materials were highly important for the life of the cell and were all required for the proper development of the organism.

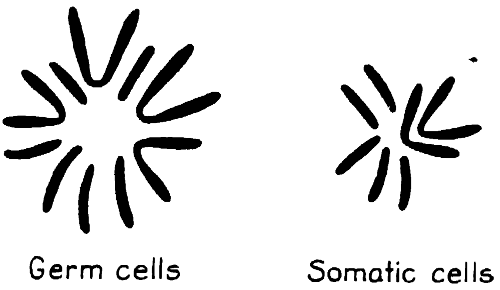
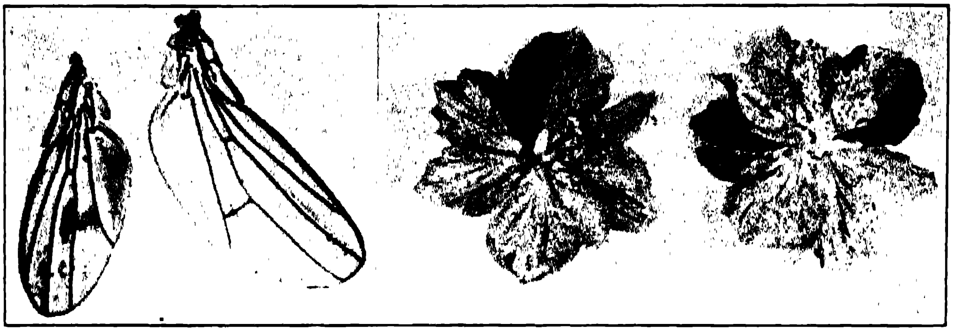


FIG. 27. CHROMOSOME GROUPS OF GERM-LINE AND SOMA IN MALES OF THE FUNGUS FLY *Sciara coprophila.*

SCHEMATIZED DRAWINGS. THE SOMATIC (BODY) CELLS LACK THREE OF THE CHROMOSOMES PRESENT IN THE CELLS OF THE GERM-LINE

This far-reaching deduction did much to stimulate further work on the subject. In fact, it may be said to have laid the theoretical foundation for modern genetics. For a long time it was vigorously opposed, and there are some even now who are inclined to regard it with marked skepticism, but the accumulated evidence of the last twenty years has served to verify it so completely that few unprejudiced students of the subject at the present time question its essential correctness.

One of its first strong supports came from another line of evidence derived



—*Courtesy Dr. M. Demereo.*

FIGS. 28 AND 29. EFFECTS OF FREQUENTLY MUTATING GENES.

FIG. 28. THE TWO WINGS OF A SINGLE FRUIT FLY, *Drosophila virilis*, IN WHICH PART OF ONE WING IS GREATLY ENLARGED DUE TO MUTATION OF A CERTAIN GENE DURING DEVELOPMENT. FIG. 29. TWO FLOWERS OF THE LARKSPUR, *Delphinium*, SHOWING DARK (BLUE) SPOTS OF DIFFERENT SIZES ON THE PINK PETALS DUE TO MUTATION OF A GENE INFLUENCING PETAL COLOR.

from the early work. This dealt with the history of the chromosomes when traced through the entire life cycle of an animal. We have already noted how the chromosomes are transmitted from cell to cell as the egg develops. But we have not yet dealt with their transmission from one generation of animals to another. This is indicated in the accompanying diagram (Fig. 16) which represents schematically the history of the chromosomes in the life of one individual. In constructing this diagram I have not taken a hypothetical case, but have used one with which I am personally familiar—a species of fruit fly belonging to the genus *Drosophila*. This fly is particularly favorable because the egg and the sperm each contain only three chromosomes, and each of these chromosomes differs from the other two, so its history may be followed individually. It will be observed that for each chromosome contributed by the egg there is a corresponding one contributed by the sperm. Consequently, in the fertilized egg the chromosomes are present in homologous pairs. In these particular animals, as a matter of fact, the chromosomes actually associate in pairs as shown in the figures.

After fertilization, during the development of the embryo from the egg, the chromosomes divide at each cell division, in the manner already indicated, so that all the cells receive the full set of chromosomes. Such a process continues consistently up to the time the final germ cells are to be formed; then in the particular cells which are going to give rise to eggs or sperms a different procedure is followed.

It is evident that if the egg and the sperm each received the full number of chromosomes, fertilization would bring together two full sets and the number would be doubled at each generation. That does not occur, however, because in these particular cells, instead of each chromosome dividing and sending daughter halves to the daughter cells, the two members of each pair of homologues come together and then separate into opposite cells, so the resulting germ cells have only half the original number.

The actual processes taking place here (collectively known as "maturation") are very elaborate and are of deeper significance than I have indicated, but the essential feature is this accurate segregation of the chromosomes so that each germ cell gets just one of each kind. Then at fertilization these single sets of chromosomes are brought together again, giving the organism the double set. Thus we find a regulatory process coming in at each generation which keeps the chromosome number from doubling. And here again we find that this specialized proceeding is not limited to a few forms but is characteristic of animals and plants generally, thus indicating in further measure the significance of the individual chromosomes.

It follows from these considerations that the number of chromosomes and the configuration of the chromosome group should be constant for each species, and this is indeed found to be the case. The chromosome groups of different species may be, and often are, very different from one another, but within a species there is constancy. Space will not permit an illustration of the various types of chromosome groups and the range of numbers found in animals, extending from two chromosomes in one of the thread worms up to more than two hundred in certain other animals (*e.g.*, some of the Crustacea), but a few illustrations may be given to indicate some of the differences which may be found within one group of animals. For this purpose I have chosen the flies, partly because this is a group with which I am personally familiar, and partly because this group is particularly favorable for the purpose on account of the association of the chromosomes in pairs. Fig. 17 is from a photograph of the chromosomes in one of the fruit flies (*Drosophila virilis*) showing the five pairs of rod-like chromosomes. Fig. 18 represents the chromosomes of another species of fruit fly (*Drosophila funebris*). The group here involves four pairs of small rod-like chromosomes and one pair of much longer rod-like ones, together with a pair of very small dot-like members in the center, so small as to be almost invisible. In the photograph shown in Fig. 19 the chromosomes in two germ cells from one of the blowflies are represented. It will be observed that these cells have just one chromosome of each kind, and that for each member in one cell there is a corresponding one in the other. At fertilization two such groups are brought together.

Finally, in the photograph from one of the robber flies, as noted above (Fig. 6) we have a still different group, with chromosomes of various shapes and sizes. Since this group is in one of the embryonic cells, before the final germ cells are formed, it has two chromosomes of each kind—*except for one particular chromosome,* the small, spherical one. This brings out the next feature of special significance for our purpose. The fly possessing this group is a male, and it has only one of these small chromosomes. The female fly of this same species, on the other hand, has two such chromosomes. They are the so-called "sex chromosomes" or "X-chromosomes." Conditions represented in this fly are typical of those in a great many animals; indeed, with a slight modification they may be said to apply to most animals, including man.

Such a relation between chromosomes and sex has long been known and has led to extensive studies on the sex chromosomes of many animals. As a result of these studies, particularly those combined with breeding experiments, it is clear that this pair of chromosomes (or this chromosome) is primarily responsible for determining the sex of the animal.

The mechanism by which this is effected is that which we have already considered in connection with germ cell formation, *i.e.*, the process of reduction in chromosome number. Since in the male there is only one chromosome of this kind present when, among the other chromosomes, the two members of a pair are separated into different cells, it has to go into one cell, leaving the other cell without any sex chromosome. As a result half the sperms receive this chromosome and the other half do not, and the eggs fertilized by the former become females, while those fertilized by the latter become males. In some forms conditions are somewhat modified by the presence in the male of a second sex chromosome called the Y-chromosome, which differs from the X in constitution and often in size. Two types of sperms are formed here, just as in the other cases, but those entering into the production of males receive the Y-chromosome instead of no sex chromosome at all. This process may be illustrated in the case of man, as shown in Figs. 20 to 22. In the first two drawings the full chromosome group of man is shown, and in the last is represented the spermatocyte division at which the X-chromosome passes to one pole, and hence to one germ cell, while the Y passes to the other. These features will be amplified later; what is desired at this point is to emphasize the fact that these particular chromosomes "determine" the sex of the animal.

Such an effect can only be produced, of course, by an influence on development, and in many cases on the development of almost all parts of the organism, for the difference between the male and female often extends to practically all the major structures of the body. It is evident, therefore, that here the processes of development leading to extensive structural differences are influenced, and in this sense controlled, by one particular chromosome, or pair of chromosomes.

Not only has this general relation been established between a specific chromosome and specific types of development, but these same studies, and others involving breeding experiments, have gone a considerable way toward showing how the relation is effected. It has been shown, for instance, in numerous animals, that the influence of the sex chromosome is not limited to sex characters, but extends to other characters as well. It has also been shown that these influences are not exerted by the chromosome as a whole in the form of a mass effect, but that within the chromosome there are discrete elements of some kind, each of which has its own specific effect. Furthermore, it has been shown that these discrete elements have a definite and constant relation to one another in the chromosome—presumably a serial order along the length of the chromosome—and that when the chromosome divides each of these divides. In other words, the evidence has provided a complete verification of Roux's hypothesis that the chromosome is composed of a series of qualitatively different, self-propagating elements.

These results have come from the combined studies of many investigators on various organisms, but particularly from the studies of Morgan, Sturtevant, Bridges and Muller on the fruit fly *Drosophila*. We can not go into the details here of how this evidence has been obtained, but a few experiments may be cited as examples of the method employed. These experiments have made use of the so-called sports or "mutations" which occasionally appear in any species of animal or plant. Familiar examples of such sports are seen, for instance, in albino animals, such as white mice or white crows or white ducks, also in many of the fancy types of pigeons, such as fantails, and many cultivated varieties of flowers, such as double roses, red sunflowers, etc.

These sports or mutations arose by sudden and apparently spontaneous changes from the parent strains (hence the name mutation). Since the characters are inherited they must be due to changes in the germ-plasm; but as already indicated, it has been found that instead of these being general changes in the germ-plasm as a whole, they are localized modifications in the individual chromosomes.

For example, in one of the fruit flies a white eyed strain arose from the ordinary red eyed type. The inheritance of this white eye character is illustrated in the accompanying diagrams (Fig. 23). When a red eyed male is mated to a white eyed female the daughters are all red eyed like the father and the sons all white eyed like the mother. The reason for this is seen in the history of the sex chromosomes, shown on the right. The X-chromosome of the red eyed father is represented in black, and that of the white eyed mother in white. We know that in the male, when the sperms are formed, only half of them receive this X-chromosome, and that the eggs they fertilize become females. The other half of the sperms will lack this chromosome (possessing the differently constituted Y-chromosome instead), and the eggs they fertilize will become males. The male, then, gets his X-chromosome from his mother and hence is white eyed, while the female gets one X from each parent; and since the red is dominant over the white she has red eyes.

In the next generation the same principle applies, although the actual results are different because the mother here produces eggs of two kinds, one with the white-carrying chromosome and the other with the chromosome carrying red. As a result both types are present among the sons and daughters alike.

Scores of other examples of this type of inheritance could be cited from many animals, including man himself, where such characters as haemophilia and night blindness are "determined" by the sex chromosome.

In the fruit fly just mentioned (*Drosophila melanogaster*), which has been studied so extensively by Professor Morgan and his associates, more than thirty characters are known to be due to separate changes in the X-chromosome. Since each of these behaves as a unit it has been possible to study their interrelations. Such studies have shown that the materials in the chromosome which are responsible for the characters also behave as units and that in the female, where two such chromosomes are present, interchanges of these units take place between the two chromosomes. It is through the study of these interchanges that the units have been shown to bear a serial relation to one another, each occupying a definite, permanent position in the series.

If this is true of the sex chromosome we should expect to find it also true of the other chromosomes; and such is actually the case, as shown by extensive studies on both animals and plants. Studies along these lines have even gone so far as to make it possible to construct diagrams or "maps" of the different chromosomes in some species, showing the relative "location" of these hereditary units, or "genes" as they are technically called. Such a map is shown, for example, in Fig. 24. It represents the X-chromosome of the fruit fly *Drosophila melanogaster*. The heavy line designates the chromosome itself and the cross markings on it indicate the "locations" of the units or genes. Just how accurately these maps represent the locations of the materials in the chromosomes is uncertain, but there is good evidence from certain special experiments, which we can not go into here, that in a general way they actually indicate the spatial relations.

As already intimated, the studies in this field have verified the conception that among the ordinary chromosomes the two members of a pair—one from the father and one from the mother—are alike in composition, whereas the members of different pairs are unlike in make-up.

The genetic evidence on this point seems entirely convincing by itself; but it may be of interest to note that the same conclusion is reached by direct observation of the structure of the chromosomes under the microscope. In many cases it is possible to see an internal structure in the chromosomes, as shown in the accompanying figure (Fig.

25) from the work of my colleague Dr. Belling, who has identified what may represent the actual genes in the chromosomes (the delicate granules). It is also possible to identify individual chromosomes by means of their internal structure. This is indicated in the accompanying figures from Wenrich's work on the grasshopper, in which the small bodies in the chromosomes are of different sizes and shapes and make up a definite architecture for each chromosome (Fig. 26).

We arrive, then, at a conception of the chromosomes as composite structures made up of multitudes of different minute elements, the genes, arranged in an orderly fashion and each playing its own particular rôle and having its own particular influence on the organism. In most cases thus far studied this influence is known only from its end result in the adult organism, but that is mainly because it is only the end result which has been studied. If the intermediate stages were followed with accuracy it would be found that the end result is due to modifications in the processes of development. Much work is being done along this line at the present time, and numerous cases are now known in which the effects of these individual elements, or genes, may be traced in the development of the organism.

Some genes, for instance, are known to affect the rate of growth, either of the entire organism or of certain parts; others are known to influence the process of differentiation—thus showing the influence of genes on both of the fundamental aspects of development. From this it is only a step, of course, to the conclusion that development as a whole is largely brought about or controlled in some way through the influence of the genes, and it is now widely accepted that in a broad sense this is true.

When we come to the question of *how* this influence is exerted, however, we come to the frontier of present knowledge on the subject and our answer can not be specific. The question will be asked at once, for example, as to how differentiation of the tissues and organs of the body can be due to the genes if the cells in these different tissues all have the same sets of chromosomes and hence of genes. This is one of the problems upon which attention is being centered at the present time. The difficulty was recognized long ago by Weismann, who developed on that account his theory of individual units or ids—a theory which anticipated many of the features established by modern genetics. In his scheme Weismann assumed that these (to him purely theoretical) units were assorted among the different tissues of the embryo as the cells divided during development, so that each cell received its own particular assortment of ids and hence went into the make-up of a particular kind of tissue or organ, with only the ancestors of the germ cells retaining the full complement of ids. It is now known that this view can not be accepted in a literal sense, but it is not yet clear as to how far it misses the mark.

In studies on this problem attention may be focussed either on the behavior of individual genes or on that of groups of genes, as represented, for instance, by entire chromosomes—and both methods are, in fact, being used. I will only cite two illustrations with which I happen to be familiar, taking first a case involving whole chromosomes. As already implied, the evidence indicates that *for the most part* there is no sorting out of individual chromosomes in development so that certain tissues receive some that others lack; but in a few cases there are indications that a process somewhat of this kind actually does occur to a limited extent.

We are working on such a case at the present time, for example, in one of the flies. In this particular species, or group of species, the evidence indicates that in the development of the male fly, as the egg divides to form the first visibly different cells of the embryo, the cells which represent the ancestors of the germ cells receive the complete set of chromosomes, but those which are to give rise to the body tissues lose three of the ten chromosomes, and hence develop with a distinctly different number, as indicated in Fig. 27. In the body tissues the two very large chromosomes and one of the smaller rod-like chromosomes are lacking. In the development of the female fly a somewhat different process occurs, which we have not yet analyzed further than to show that the body cells have eight instead of seven chromosomes.

It is of interest to note also, in connection with this case, that we have been able to show that the type of chromosome elimination which occurs here is predetermined, before the egg begins its development, by the genes in one particular chromosome of the mother producing the egg. Although it seems certain that this process of chromosome elimination is not of general occurrence in other animals, its presence here indicates that particular influences may be brought to bear on particular chromosomes at definite stages in early development, and that these are due to specific genes.

When consideration is given to the other mode of study, *i.e.*, following the behavior of *individual genes* during development, particular interest attaches to those cases in which certain genes have the property of changing during the course of development. What the nature of this change is, or how it occurs, is not known, but it leads to definite influences on development and promises to be very useful for further study. It is responsible, for instance, for certain types of variegation in plants and of mosaic pattern or spotting in animals. An illustration of this is seen in the case of one of the fruit flies being studied by my colleague, Dr. Demerec, as shown in Fig. 28. Here a certain gene, which affects the size of the wings, changes (mutates) frequently during the course of development, producing enlarged regions in the wings. In this particular specimen nearly all of one wing is enlarged.

Similarly in the variegated flowers of the larkspur, Delphinium, which he is studying, the dark patches of blue on the pink petals (Fig. 29) are due to such spontaneous changes of a certain gene which influences the production of color. How much this phenomenon of changing of individual genes in different parts of the body during development may have to do with explaining differentiation in general is not known. It may be one of the factors involved, but at present it seems probable that ordinarily most of the genes do not change their make-up during development, and that their differentiating influences are exerted in some other manner.

The subject of gene function, however, is still in its infancy, and at present only theoretical interpretations can be offered. In a general way, it may be said with some confidence that the genes represent chemical materials and that these chemical units influence the physiological processes in the cells and cause the cells to interact upon one another in a certain manner and in a certain sequence.

It is generally agreed, I believe, that development represents a chain of processes, each one of which influences, and to some extent determines, the nature of subsequent ones. Consequently we may, perhaps, picture the story in a hypothetical way somewhat in this fashion: Starting with an egg of a given composition and structure, which has been determined primarily by the genes of the mother, development is induced by the entrance of the sperm, which brings in a set of genes from the father, and then proceeds under the influence of these two corresponding sets of genes, each gene performing its own function in influencing conditions and processes in the cell and probably being influenced in turn by conditions already existing in the cell.

One view also postulates that at the beginning, owing to the particular materials and conditions in the cell, certain genes are stimulated to greater activity than others, and that as development proceeds other genes become more active at certain times and in certain cells, due in part to the position of these cells in the embryo and to the different distribution of other than chromosomal material, as the original materials of the egg (cytoplasm) are apportioned to the various cells descending from it. On this hypothesis we may picture a reciprocal action going on between the genes and their surroundings, the genes at one stage determining to some extent what the surroundings are going to be at a later stage and these in turn causing certain activities of the genes or chromosomes which will predetermine to a certain extent what is going to occur at a still later stage.

This is only one of the various possible views, and is, of course, an extremely crude picture; but to attempt a detailed and specific interpretation of the functional processes at this time would not only take us deeply into physiology and biochemistry, but would lead us farther and farther from the foundation of actual experimental results. This aspect of the question, therefore, must be left for the future, and we must be content at present to have obtained a fair idea of why the chromosomes, or genes, may be looked upon as playing a primary rôle in the processes under consideration even if we know little about how they do it.

THE WATER SUPPLY OF CITIES IN THE UNITED STATES

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THE problem of distribution of water to urban communities in the United States varies with conditions and may be considered under categories of quantity and quality. Quantity is a problem in arid and semi-arid communities of growing population and humid areas of dense settlements, while in the moderately densely and sparsely settled areas under humid conditions an ample supply of water can be obtained. Quality, the desideratum being a water that is clear, tasteless, free from pollution and soft, does not lend itself so easily to regional distribution; turbidity occurs where the source of supply is a river and is slight in impounded waters; taste is a seasonal and at times a local phenomenon; pollution arises from the character and density of populations; and hardness results from the soluble character of soil and rocks.

SOURCES OF SUPPLY AND CONSUMPTION

There are 68 cities in the United States with a population in 1920 of over 100,000. Of these five obtain their supply of water from the Great Lakes; Chicago and Milwaukee from Lake Michigan, Detroit from the St. Clair River; Buffalo and Cleveland from Lake Erie. Twelve receive their supply from great rivers: Minneapolis and New Orleans from the Mississippi River; Cincinnati and Louisville from the Ohio River; Nashville from the Cumberland River; Washington from the Potomac River; Kansas City, Missouri, Omaha and Kansas City, Kansas, from the Missouri River; and Albany from the Hudson River. Seven cities of this class—Memphis, Spokane, Lowell, Houston, Camden, San Antonio and Dayton—obtain water by sinking wells. Rochester, New York City, Indianapolis and St. Paul use wells in part. The remaining forty-two depend on surface drainage or small streams and ponds with a fluctuating flow and in most cases limited in amount. Denver, for example, finds that the water supply from the South Platte River is not sufficient for her future needs, and plans the diversion of water from the west slope of the Rocky Mountains. The new Moffat Tunnel can be used only on the Fraser River to divert 106,000 acre feet, which is less than her demands will be in the near future as based on her population curve. The entire plan involves a total diversion of 250,000 acre feet through the mountains. On the other hand, San Francisco, on the completion of the new Hetch Hetchy system, together with the Spring Valley Water Company, recently acquired by the city, will have 62,000 acres in the water shed with a capacity of 65,000,000,000 gallons, and this will yield even during a succession of seven or eight seasons of scanty rainfall a daily quantity in excess of her needs. In the densely settled sections of the United States and particularly in the area from Pennsylvania to Massachusetts, where surface drainage is largely the source of the water supply, it is estimated that with proper storage facilities the yield will average about 500,000 gallons per day per square mile.

The average consumption of water per day per capita for 200 cities in the United States is about 140 gallons. There appears to be no strong correlation between per capita consumption and population, although in general the smaller cities have a less per capita consumption than the larger. Cities having a population of 500,000 or over in 1915 had a per capita consumption of 150; those between 300,000 and 500,000, 149; those between 100,000 and 300,000, 123; and those between 30,000 and 50,000, 123.[1] Consumption is a variable dependent also on the type of industry.

Cities with excessive per capita consumption include: Tacoma, 430; Buffalo, 324; Pittsburgh, 253; Albany, 230; Chicago, 226, and Salt Lake City, 203. And with a low per capita consumption: Fall River, 48; Hartford, 64; Providence, 65; St. Paul, 70; Worcester, 78; and Memphis, 87.

The excessive use of water is due to waste, and metering is the only remedy. This conclusion is supported as follows:

> Seventeen New York State cities which pumped at least a part of their water by steam or electric power had 75 per cent. or less of their systems metered. The average per capita consumption of these was 234 gallons per 24 hours. Six of these reported a per capita consumption above this average. Fifteen cities in New York State, which pumped at least a part of their water, either by steam or electric power, had more than 75 per cent. of their systems metered. The average per capita consumption of these was 99 gallons per 24 hours. Seven of these cities reported a daily per capita consumption in excess of this average. Of the 201 American cities having at least 75 per cent. of their system metered, the daily average per capita consumption is 96 gallons.
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> The daily average per capita consumption of New York State cities whose systems were 100 per cent. metered was 98 gallons, and the average of American cities all of whose services are metered is reported to be 85 gallons.[2]

Tacoma, which stands at the head of the list of excessive per capita usage, admits that there is a large wastage by overflow and but 8 per cent. of the water is metered. Buffalo has but 32 per cent. of water metered; Pittsburgh 15 per cent.; Albany 33 per cent.; Chicago 22 per cent. and Salt Lake City 33 per cent., while the cities of low per capita consumption are metered thus: Fall River 57 per cent.; Hartford 100 per cent.; Providence 70 per cent.; St. Paul 61 per cent.; Worcester 74 per cent.; and Memphis 60 per cent.[3]

Cities have accomplished much in providing water but little in the economical use of it.

ADEQUACY OF SUPPLY AND CONFLICTS IN USES

The larger problems of water supply in arid and semi-arid lands are in general known. In humid areas where many people reside the problem of water supply becomes acute in those regions where the source of supply is drawn from secondary streams. Great Lakes cities have an abundance; cities drawing water from large rivers are practically immune from shortage. Even during the excessive droughts of the summer of 1930 no city tapping the Mississippi River or its large tributaries reported any danger of failure of their water supply, although the Mississippi River was making a new record in low water stages.

Eastern cities were not so fortunate, and during the past summer (1930) drought conditions caused water supply boards to prohibit in instances the use of water for lawns and the washing of automobiles. Schools have been closed, Monday wash day banned, tub baths limited to one a week and even a drinking water shortage threatened: while country places have been in many cases in distress. In many cities the supply is adequate if rains are fairly regular, but a serious deficiency of water is the experience of too many communities when a long dry spell is experienced.

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[1] General Statistics of Cities, 1915. Washington, 1916.

[2] "Water Consumption in New York State Cities and its Effect on Coal Consumption." Special Report, Albany, N. Y. August 11, 1922.

[3] The percentages are taken from "General Statistics of Cities, 1915." Department of Commerce, Washington, 1916.

To-day, in the eastern populated district, towns and cities are competing for drainage areas, and protection for present supply and particularly for future needs is a new problem that must be considered. No adequate estimate of future requirements has been made and no great regulations covering the rights of other communities have been formulated. As an example: The construction of a new reservoir to supply the city of Boston is meeting opposition. The State of Connecticut filed a bill of complaint with the Supreme Court during January, 1928, against the Commonwealth of Massachusetts for planning to divert the waters of the tributaries of the Connecticut River—the Swift, Ware and Miller Rivers—from their natural flow into the Connecticut.

Briefly, the State of Connecticut makes the following charges:

(1) The navigability of the Connecticut River would be impaired by any diminution of the natural flow of the river which would result in a flow too slow and sluggish to free the bed from sand bars.

(2) The flood stage would be lowered and the inundation of flood plains which gives the soil its great fertility will be lessened.

(3) The pollution of the stream by Massachusetts and Connecticut industrial plants and city discharges is large, and unless the full flow of the Connecticut is maintained this will not be removed but remain as a detriment to health.

It is expectable that unless the entire area be studied in reference to present and future needs of water, instances of this kind will multiply.

THE CASE OF LOS ANGELES

Los Angeles, settled in 1781 on the Los Angeles River, obtained from King Carlos III of Spain by royal decree the ownership to all the waters of the river in perpetuity. Until 1914 this was practically its only source of water, and it was considered sufficient to supply a population of 250,000.

When Los Angeles passed the quarter century mark and the Los Angeles River, described as a stream whose bed must be sprinkled regularly to keep down the dust, became inadequate the city tapped the Owens River, 250 miles away. Owens Valley is about 150 miles long, lying between the Sierra Nevada Mountains on the west and the White Mountains on the east. Practically all the drainage is from the Sierra Nevadas between Mt. Lyell and Mt. Whitney. The river empties into Owens Lake, and the latter has no outlet. Previous to 1905 the valley had a population of about 3,500, who gained a livelihood by farming on lands irrigated by the river, since the rainfall of the valley is light—probably not over 5 inches per year.

In areas of limited precipitation, conflicts frequently arise over rights, and it is not strange that, when Los Angeles went beyond her borders for water, trouble followed. The intake of the Los Angeles system on the Owens River was below the headgates of the lowest irrigation ditch,[4] and consequently the city could not deprive the farmers of water, but on the contrary it took at the beginning only such water as would have gone into Owens Lake and eventually evaporated. In reality Los Angeles benefited the Owens Valley farmers by connecting them by rail with the outside market. This boon acted as a boomerang, since it offered inducements to settlers, and the population by 1920 had doubled and a tourist trade had been inaugurated. With this increase in population and a corresponding withdrawal of more water from Owens River by the settlers, Los Angeles found in 1923 that the leavings were not sufficient for the city's needs and began to buy land of the farmers to lessen the irrigation drain. Altogether 80 per cent. of the irrigated lands of the valley were purchased. In 1924 there was an outbreak by the farmers, aqueduct waste gates were opened or dynamited and about 200,000,000 gallons of water were turned into the desert.

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[4] "The Owens Valley Controversy." *Outlook*, 146, 341-3, July 3, 1927.

To-day Los Angeles, beyond the million mark in population, is looking forward to a city of 2,000,000 people and must have more water than can be gained from the Los Angeles and Owens Rivers. She has already surveyed an aqueduct route to the Colorado River—260 miles away—to carry 1,500 seconds feet of water. The Colorado River has not an adequate amount of water for all the requirements of the section. The U. S. Geological Survey estimates that at Parker, when the water is first turned from the river for use, the annual supply will be about 9,593,000 acre feet. Irrigable lands below Parker will demand 9,909,000 acre feet; in Mexico, 3,357,000 acre feet is the probable ultimate need for irrigation; and Los Angeles and other Southern California cities are calling for 2,000 seconds feet, equivalent to 1,448,000 acre feet for domestic purposes: a total of 14,714,000 acre feet—or 4,805,000 acre feet more than is allotted to the Lower Basin of the Colorado River by the Colorado Compact of 1922.[5]

There is some difficulty anticipated in this instance, as in the Owens Valley case, before the Colorado Basin residents yield this amount of water.

THE CASE OF NEW YORK CITY

The domestic water supply in humid regions of dense population is obtained perhaps with greater ease than in arid areas but is beset with difficulties no less acute. New York City's water supply is able to yield 1,100,000,000 gallons of water a day. This water comes from a number of sources: the Catskill system, the latest addition to the city sources, has a maximum of 600,000,000 gallons per day; the Old Croton source of 1842 turns to the city 336,000,000 gallons per day; the Ridgewood system, an extensive underground supply developed on Long Island, adds 90,000,000 gallons per day; old borough sources in operation before their incorporation furnish 30,000,000 gallons per day; and private water companies which still hang over from earlier days are estimated to yield 44,000,000 gallons per day.

The city is using now about 850,000,000 gallons daily. It is estimated that the annual increase in the amount of water is about 31,000,000 gallons daily[6] and if this increase continues for eight years the entire available supply of water will be in use; and within ten years there will be a serious shortage of water. This present condition repeats the history of the water supply of New York beginning with the wells and springs that served 1,500 people in 1664 until late in the year 1915, when the Catskill water was turned into the distributing pipes. Until the Old Croton Dam was constructed (1837–1842) the city was not large enough to demand a water supply from outside her boundaries. The various units of New York's water system represent in part the development of her constituent parts before their union as Greater New York, and in part old contracts by private water companies in the days before public water companies were much in vogue.

At the beginning of the nineteenth century there were in existence 16 waterworks systems in the United States. One of these—Winchester, Virginia—was under public ownership, and the remaining 15 were privately owned. The percentage of public water plants rapidly increased during the century from 6.3 (1800) to 53.2 (1896).

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[5] For a survey of this problem see Robert M. Brown, "The Utilization of the Colorado River," *Geog. Rev.* XVII: 453–466, July, 1927.

[6] C. G. Poore, *New York Times*, xx: 5, Sunday, April 10, 1927.

Only one of the original 16—that of Morristown, N. J.—continues under private ownership. New York's first publicly owned waterworks were constructed in 1830 and yielded 21,000 gallons of water a day. This was an almost insignificant amount in comparison with the Manhattan Company, a private concern, that had a maximum capacity of 700,000 gallons a day. It was however a beginning, and the additions to the water supply were made more and more by the city itself.

In the meantime the boroughs, as they in turn faced the demand for water, developed independent systems of their own.

While New York is built on a rocky island and has therefore a limited water table, Brooklyn is situated on glacial sands and gravels which extend eastward throughout Long Island. The underground water about Brooklyn in 1926 yielded 104,000,000 gallons per day; 73,000,000 gallons of this was taken from wells from 30 to several hundred feet deep; 34,000,000 from infiltration galleries laid for 6 miles 10 to 15 feet below the water table; and in addition Brooklyn received 20,000,000 gallons a day from surface supplies.

New York City covers an area of 315.9 square miles and has an average rainfall of 44.63 inches. If the entire precipitation of an average year over the city was impounded it would amount to 204,125,707,138 gallons or an average of 559,000,000 gallons per day.[7] Only a meager percentage of this is available, since with paved streets the run-off is excessive. The water shed of New York's water system, not counting the Queens and Richmond supplies, is 1,136 square miles—an area equivalent to the State of Rhode Island. This is a little in excess of two square miles for every 10,000 people. The Queens and Richmond areas would probably bring it to three square miles, which is the average amount of drainage space per 10,000 people, utilized by cities dependent on surface water.

For a future addition to her water system there is the proposal to increase the water sheds above the Croton Dam on the east side of the Hudson. This, it is estimated, will add half a billion gallons of water per day to the system and will take care of the increases of population in the city for the next twenty years. There seems to be a little chance to save much from wastage, since the per capita daily consumption in New York (102) is considerably less than any of the other large cities and much below the average for 200 cities (139).

Treatment for Potability, Purity and Industrial Uses

The character of raw water varies greatly. The Great Lakes' waters in their natural state are ideal potable waters, but they are disagreeably polluted by the cities located on them. Topographic conditions at Chicago and Milwaukee compel the cities to dump their sewage, and some of it is untreated, into their sources of water supply. This is overcome partly by placing the intake of the water system far out into the lake—6,565 feet in 67 feet of water for Milwaukee and from 2 to 4 miles off shore for Chicago—and partly by sterilization.

Buffalo has its intake 1¼ miles from shore. Chicago's attempt to settle the problem was to reverse the flow of the Chicago River, but this did not settle the difficulty, for other Illinois towns and neighboring cities continue to contaminate the waters of the lake.

New Orleans has experienced great difficulty with its water supply. Up to the time the present system was put into operation the city depended in part for its water on cisterns which stored the rain water drained from its roofs, and from a private company which served the raw Mississippi River water. Since 1909 a carefully treated river has been served the city which is advertised as "a clear, pure water of the most desirable quality."

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[7] Edward H. Hall, "The Catskill Aqueduct," New York, 1917.

The long journey of the waters of the river from other valley cities which pollute it is in itself a cause of self-purification, and apart from its turbidity—650 parts per million of suspended matter—it is usable.

A few localities are fortunate in obtaining water without treatment, believing with Worcester that "clean water sheds, impounding reservoirs which are kept free from pollution and long storage of water are the best agents for purification."

San Francisco has its water basin carefully excluded from contamination and neither purifies nor filters its supply.

Portland, Oregon, has nothing to pollute its supply, and filtration they claim will never be necessary. New Bedford uses no artificial purification.

The process of cleansing polluted water has reached so high a degree of perfection that almost any raw water may be rendered clear, palatable and safe. An early stage in the process is *sedimentation*. Some of the water used is very turbid. The river water at St. Louis averages 1,430 parts of suspended matter in a million, but the settled water averages but 25 parts; at Atlanta the turbidity runs at times as high as 5,000 parts in a million, but at other times it falls as low as 100; at New Orleans the Mississippi River averages 650 parts; the Missouri at Kansas City 3,100 parts. Lakes to a large degree because of low movement are settling basins and can normally be expected, where not agitated, to have a low turbidity. The Detroit supply is as low as 35 parts per million.

Water with sulphate of lime and magnesia has a permanent hardness that may be reduced a little with difficulty; water with carbonates of calcium and magnesium has a temporary hardness which may be largely eliminated. Hard waters demand a softening process before the proper detergent action of soap can be brought into play. Furthermore, their use in boilers is undesirable because they produce boiler crust and scale by the deposition of the salts present. The Catskill water (New York) is well suited for business and household purposes, for it is very low in iron content and corrosive constituents.[8]

The city authorities sum up the advantages of a soft water: a soft water reduces the use of soap in laundries and in silk dyeing; and affects favorably the operation of power-houses, breweries and photographic establishments. A soft water with low corrosive action eliminates to a great extent scale in boilers and corrosion of tubes, thereby reducing the cost of steam production and the probability of accident. The use of softer waters means the aggregate savings of hundreds of thousands of dollars affecting many classes of consumers in Greater New York.

The Camden water supply board speaks of its soft water in this way: "People taking a bath have here no difficulty in getting soap to lather. In the Middle West it is a hard job."

Within a comparatively brief period of time the water supply of cities has changed from a pestilence bearing medium to an exceedingly pure supply. In Richmond the death-rate from typhoid fever in 1908 was 49.7, and it averaged 59.4 per 100,000 persons for the ten years previous to that date. Settling basins were put into operation late in 1908 and in 1909 the death-rate due to this disease fell to 24.1 and averaged during the next 15 years 12.2. In 1924 a filter plant was put into operation, and the death-rate again fell to 5.4 for 1925 and 1.1 for 1926. The typhoid death-rate in Los Angeles for the year ending June 30, 1925, was 1.07 and New York City 2.0. Now New York traces typhoid to oysters, milk, uncooked vegetables and ice cream and to carriers from outside the city, while Los Angeles claims that 50 per cent. of the typhoid fever comes to-day from outside the city. Wilmington, Delaware, following purification processes, reports a 26.9 per cent. reduction in the typhoid death-rate.

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[8] "The Municipal Water Supply System of the City of New York," Dept. of Water Supply, Gas and Electricity. April, 1923.

The Denver report on its water system says that the death-rate in all cities from typhoid fever is greatly reduced when filter-plants are installed, and that there is a second reduction in the death-rate when the practice of sterilization of the water with chlorine is adopted. The typhoid death-rate in St. Louis per 100,000 persons has diminished from 47 in 1903, 17 in 1913, 4.2 in 1923 to 3.8 in 1924.

Again in Jersey City in 1891, using the Passaic River as its source of water, the typhoid fever death-rate was 101.3 per 100,000; in 1898 from the Pequannock it was 40.6 and 1906 from the untreated Rockaway River, 21.6. In 1913 hypochlorite of lime was used, and the death-rate fell to 10.3, and finally in 1926, following the use of chlorine, it fell to 1.57. New Orleans, which originally used raw water with disastrous results, reported a death-rate for typhoid fever of under 2 per 100,000 persons in 1925. To-day water supplies can be practically absolved as carriers of diseases, and only negligence of the most flagrant character will make the water system of a city dangerous.

CONCLUSION

Engineering and chemical investigations have subjected raw waters to various processes, so that the quality of water is attaining a high degree of potability. Sedimentation reduces turbidity; sulphates of alum or iron complete this work; filtration removes harmful and undesirable bacteria; chlorination complements filtration; aeration adds oxygen, which eliminates taste and odor due to destroyed bacteria; coppering aids in removing taste; and sulphates of lime and magnesium tend to remove hardness.

Investigations promise in the near future an absolutely tasteless water. Thus the waters of the land may be brought to the household clear, tasteless and sanitary and to the factory soft and clear.

The great problem that remains is the quantity of water in the face of growing populations. Systematic investigation, not of a city's possible resources, but, so that a proper and satisfactory distribution of surface waters may be made without infringement on the rights of others, of the water resources of an extensive area containing many urban groups is the need of the immediate future.

WHENCE OUR METALS?

By NAHUM SABSAY

NEW YORK, N. Y.

WHERE did our gold, silver, platinum, copper, lead, zinc and other metals come from? Why are they found in comparative abundance in some places and not at all in others? Why are metal deposits usually confined to the mountainous regions? And why do they, with few exceptions, always lie in vicinity of, and even in, rocks that were formed by cooling and consolidation of once hot and liquid material?

At present these questions can not be answered with absolute certainty. Geology is no exception to other sciences. It reveals much to the searchers, but it conceals immeasurably more.

However, inadequate as geological knowledge still is to solve the many baffling and often mystifying problems confronting geologists, it is, on the other hand, sufficiently strong to evoke a general picture of the earth's past, and, specifically, the picture of metal deposition.

To begin with, they clearly see that phenomena like the periodic eruptions of Vesuvius, the boiling lava in the crater of Kilauea, the Katmai explosion, the fumeroles of the Valley of Ten Thousand Smokes, the blowing off of Krakatoa, the incandescent dust and gigantic spine of Mt. Pelée, the Icelandic outwellings of lava, the geysers, the hot springs—in short, all the manifestations of the activities of the liquid and hot rock-material within and beneath the crust of the earth—are mere vestiges of the events which in the past geological ages had repeatedly taken place on a staggering scale at and below the surface of the earth.

Time and again during those fabulously removed ages and in place after place inconceivably large masses of highly heated, liquid rock-materials rose from the depths and injected themselves into the earth's crust or, if they reached the surface, spread over it, burying vast areas underneath; creating all kinds of bizarre, phantasmagoric and majestic phenomena; working all kinds of titanic destructions.

Geologists also see that these intrusions and extrusions of the liquid materials are most intimately connected with the formation of the metalliferous deposits and that the beginning of the story of such a deposit is the same as the first part of the story of a nearby intruded mass.

From how far below did these materials, or *magmas,* as they are technically called, come? No one knows. Just as no one knows whether they all came from the same centrally located reservoir or from a number of separate magmatic pools which lay immediately below, or perhaps within, the earth's crust.

Nor does any one know whether magmas, before they rose, were actually liquid or only potentially so, ready to liquefy as soon as favorable conditions were created. Nor does any one know what were exactly the processes of magmatic rising and excavation of the incredibly large crustal chambers which the solidified products of those magmas are now seen to occupy.

The intrusions of magmas and extrusions of *lavas*—as magmas which reach the surface of the earth are called—were mainly confined to the regions where new mountains were being born or where the old ones were undergoing reelevation. Here, where the rocks were being folded, domed, arched, warped, fractured, displaced, and the whole region was being slowly uplifted to great heights, the magma, or magmas, stored somewhere underneath that region, found the best opportunities to come up, to invade great stretches of rising country, to penetrate its very heart, and thus to bring into it the materials which were to become the core, or cores, of the mountain ranges. Here also these materials found an opportunity to reach the surface through a number of volcanoes and fissures in the crust, to spread over areas of thousands and tens of thousands of square miles and to pile up lava flows hundreds and thousands of feet high.

Those lava flows, as can be seen from their vast remnant, were stupendously large masses of ejected liquid material. Yet when compared with the masses of the material *injected* into the growing mountain ranges, they no longer seem so large. The more or less centrally located, elongated and irregular, subterranean chambers within some of the present ranges—chambers that once were filled with magma but now are occupied by its solidified products—are over a thousand miles long, two or three hundred miles wide, and of unknown depths. And this is not all. Scattered round about these there are other magma-product filled chambers, some small, some large and some immense. Then there are magma-product filled fissures—narrow, wide, short, long—some closely spaced, some spread wide apart, and all together crisscrossing the region in a wide and irregular network. And there are enormous layers of similar product squeezed in between beds of the country rocks and into any other weak zone which the mountain-building processes had produced.

Having injected itself into all those subterranean enclosures, the magma did not remain liquid and hot. It cooled; gave out most of its volatile constituents; crystalized, first partially and then completely; and finally turned into one, or several varieties of the rocks that make up the crust of the earth.

The rate of cooling, crystallization and final consolidation of magma varied, of course, with its mass and its distance from the surface of the earth. When close to the surface and in small enclosures, such as fissures, for instance, the cooling was rapid and the process of crystallization comparatively simple. In the larger chambers and at great depths, magma remained liquid and hot for a long time and in them the process of crystallization was highly complicated, so complicated indeed that it is still but poorly understood. The longer the magma remained liquid and the richer it was in the volatile substances the more it reacted with the surrounding host rocks, often creating in them a number of important and extensive changes, and sometimes altering them completely, thus producing entirely new rocks.

There were a number of factors which influenced the extent and the character of alteration produced by magma in the surrounding country rocks not only from one magmatic chamber to another but also around the periphery of the same chamber. And one of those—and an extremely important one—is the variation in the amount and nature of the volatile constituents which the magma had contained. It is the volatile substances that are mainly responsible for the rock alterations and also for the formation of the metalliferous deposits.

Now what are those volatile substances?

Directly, geologists know very little of them. This is natural since all they can see now of the ancient magmas are the cold and solidified magmatic products, that is, the crystalline rocks, from which all the volatile substances had gone. And in the country rocks in which a part of those substances were retained, they are no longer what they had once been. Here they combined with some of the constituents of the host-rock and formed a multiplicity of minerals. The rest of the volatile substances had reached the surface, mingled with surface and ground waters and with the atmosphere and thus they are lost for investigation.

Indirectly, however, geologists have a fair conception of what those substances were. They know that most, if not all, of the magmas contained incredibly large amounts of steam or superheated water. They know that many of the magmas contained large quantities of sodium, potassium, chlorine, fluorine, boron, carbon, and a number of other elements. And they believe that some of the magmas carried, in varying proportions, several of the precious, semiprecious, and base metals—gold, silver, copper, lead, zinc, antimony, arsenic, cobalt, nickel, and others—and a prodigious amount of sulphur, in combination with which most of the metals are usually found.

The escape of the volatile substances from the larger magmatic chambers—they went away as gaseous or aqueous solutions, called by geologists *mineralizing* solutions—was a drawn-out affair. While it was going on, the magma, as stated, was slowly cooling, crystallizing, consolidating, cooling still further till it took the temperature of the surrounding rocks. And thus, depending on the chemical composition of the particular magma, the rate of cooling and crystallization, and several other circumstances, some of which are not yet clearly understood and some entirely unknown, one kind or another of the crystalline rocks was formed. Often, by the process of differentiation several of them were produced all from the same magma and even in the same magma-chamber. This is the origin of the *intrusive* or *igneous* rocks—the granites, gabbros, diorites, and nearly two thousand others which all together compose by far the largest part of the *whole* of the earth's crust.

This brings us to the question of the other rocks—the rocks which the magma had intruded, through which it expelled all its enormous quantities of water charged with other volatile substances, and which it often mineralized and sometime enriched with valuable metals. What are those rocks?

In parts these are older igneous rocks which had been formed in still earlier geological ages by other magmatic intrusions. In part these are *extrusive* or *volcanic* rocks like basalt, rhyolite, obsidian, tufa, all formed by cooling and solidification of lavas or by consolidation of volcanic ash. But the most important part of these rocks is of altogether different character and origin. It is composed of *bedded* or *stratified* or *sedimentary* rocks like conglomerates, sandstones, shales, limestones, which were formed by slow accumulation of the sediments on the shores and bottoms of ancient inland seas—seas that existed where these rocks now rise in mountainous masses. And it is through these rocks that the mineralizing solutions most often traveled and deposited in them their mineral load.

All rocks, surrounding the magma-filled chamber were usually greatly shattered and fractured by the mountain-building processes and by the injection of the magma. This shattering and fracturing had produced a system of channelways offering the magmatic solutions avenue of escape. If, however, no such channelways were available or were not adequately numerous or large, the solutions, propelled by the high pressure in the magma, took advantage of the porosity of the country rock no matter how minute this porosity was, and bodily forced their way through it. Often they made use of their ability to dissolve some of the constituents of the country rock, and thus "ate" their way through unfractured and compact rock masses.

No matter what road these solutions took or how devious their courses were or how far they traveled, they eventually mixed with ground waters or came up to the surface where they emerged as springs often still hot—sometimes as steam—and still mineralized. And thus they added a new supply of water to that which had existed in the ground and at the surface—a supply which till then was locked in the bowels of the earth and had taken no part in the perpetual circulation of the ground, surface and atmospheric waters.

Only, upon issuing at the surface, the solutions were different from what they had been when they parted from the parental magma. They were much cooler, greatly impoverished in the mineral content, and whatever mineral substances they still retained were mostly derived not from the magma but from the country rocks.

What did they do with the other substances? Where did they leave them?

They dropped them. Dropped them in the form of various minerals. Dropped them partly here, partly there, sometimes all in one place, sometimes scattered far and wide, sometimes close to the magma, sometimes far from it both vertically and laterally, sometimes near the then earth's surface, sometimes at great depths. They dropped them wherever favorable conditions were met or wherever they were forced to do so. They dropped them in open fissures and in any other open space they happened to be passing through, filling and sealing them completely. And they had left them in the massive rocks in exchange for other mineral substances which those rocks were willing to give up.

And if in the original load there were some of the valuable metals, these, too, were dropped. And if the solutions did not scatter these metals, but tucked them away within comparatively small spaces, then valuable ore bodies resulted.

It is seldom possible to tell exactly why the solutions chose the particular area in the magmatic chamber to escape through; the particular distance from it to deposit part or the whole of their load; the particular horizon; the particular rock; the particular zone in that rock. In fact, the entire behavior of the mineralizing solutions at times seems to be extremely capricious. They are known to have repeatedly played many a strange and unexpected trick which now perplexes geologists when they try to reestablish the course these solutions followed and the affinities they exhibited towards the various rocks.

What was the time consumed by the expulsion of all the volatile constituents of the magma and by the cooling and solidification? This question geologists must answer with many reservations, and even then only in a general way.

They think that in the fissures and other small enclosures which lay close to the surface, the cooling and solidification were accomplished within a few weeks and months from the time the injections were completed. They believe that here the crystallization was comparatively a simple process. For the cooling and solidification of the magma in the larger chambers and in those that lay far below the contemporary surface, they think tens of years must have been necessary and that correspondingly, the process of crystallization was here much more complicated. And they think that it required hundreds and thousands of years to turn into solid rock all the magma that now constitutes the core of the large mountains. This is about all geologists can say regarding the duration of the cooling and crystallizing processes. They might add, however, that long as the expulsion of the magmatic solutions and the mineralization of the country rock might seem when regarded in terms of human life, the mineralizing process, when compared with the entire duration of the birth and growth of the mountains, seems a fleeting moment merely.

With the injection of the magma or magmas into the growing mountains, the folding, arching and fracturing of the rocks did not end. The disturbances continued. The history of the mountains was still in the making. It has never ceased to be. And it is with the post-intrusion history of the mountains that the history of the newly formed metalliferous deposits becomes from now on most closely connected.

The continued uplifting sometimes of the whole region, sometimes of only local new injections of magmas, new volcanic eruptions, new arching, folding, doming broke up the rocks into large and small blocks often cutting across the newly formed or previously existing ore bodies. This was followed by new readjustment of rock blocks; new slidings of one past the other; some moving upwards, some downwards, some sidewise; moving into all possible directions for all kinds of distances. It was thus that many an ore body became cut up into pieces and the various parts widely separated from each other. And it was thus that occasionally the whole ore body with the enclosing country rock was moved far away from its original position.

Meanwhile an entirely different kind of activity was going on above, at the surface. Heat, frost, atmospheric waters, plants, burrowing animals, acids of the soil were tirelessly and ceaselessly attacking the exposed rocks, eroding them away, carving them into peaks, ridges, cliffs, valleys, canyons, gorges. At the same time the rainfall, winds, streams were washing down the fine and coarse débris, transporting them to the inland seas where currents and waves assorted them, spread them out and deposited them in alternating beds of graded material. Here these beds have often accumulated to thousands upon thousands of feet in total thickness and consolidated under the enormous pressure of the overlaying layers, thus forming series of sedimentary rocks. In time these seas had drained, the newly formed rocks uplifted, and either remained as the more or less flat veneer that constitutes nearly everywhere the upper part of the land's crust or were raised higher and folded into mountains and highlands which in turn were intruded by magmas and capped by lavas, and sometimes enriched by valuable minerals. And the cycle continued.

But to return to the ore bodies which we left somewhere below the surface of the mountain which is undergoing erosion.

As the erosion proceeded deeper and deeper, the top of now one or another of the ore bodies became exposed and, as the erosion proceeded still farther, the ore minerals, the mixed-in-with-them, valueless minerals—the *gangue*—and the surrounding country rocks also became gradually disintegrated.

The disintegration of the metallic minerals freed great quantities of sulphur with which, as already stated, most of the metals were or had been combined. The freed sulphur, uniting with oxygen of the air and with the ground and atmospheric waters, formed weak solutions of sulphuric acid and these dissolved the metals. These new metal-bearing solutions either carried the metals lower down where they enriched the still undecomposed metallic minerals, or dropped them in other places where favorable conditions for deposition existed, or mingled them with the circulating ground waters and thus frittered away great wealth. Even in the first two cases the saving of the metals was only temporary. Eventually the erosion reached the enriched and redeposited metals—these are called *secondary* deposits—disintegrated them also and carried away their metals to some other region, to the rivers, seas and oceans.

Many of the ore deposits were thus completely destroyed in the past geological ages. Some of them were still undergoing destruction when man appeared on earth. In time, these deposits, too, would have been completely lost had not man learned the uses of the metals, learned how to mine them and how to extract the metals from the worthless ingredients.

By now nearly all the deposits which the erosion of the earth's surface had uncovered have been located except, of course, those which still might be found in the little known parts of the world. Most of the high and fairly high-grade deposits located, both those which outcrop at the surface and those which lay at some distance below it and had been discovered by underground explorations, are very well worked out and many entirely exhausted. And while it is true that there still remain a great many of the low-grade deposits of which only, comparatively, a few are mined, the mining of most of those is at present not a profitable affair. It is for the still hidden rich ore bodies—ore bodies which may lie almost any place in the mineralized and ore-bearing regions and give no intelligible signs of their whereabouts—that mining engineers and geologists are eagerly searching. And the search for these is a long, laborious, expensive, and, above all, uncertain and precarious task.

INSECTS IN ENGLISH POETRY

By PEARL FAULKNER (Mrs. C. O.) EDDY

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(Continued from the July issue)

In praise of Erinna, the little maid who followed so closely in Sappho's tread, some one says:

This is Erinna's honeycomb, though small
'Tis of the Muses' sweets commingled all;
Three hundred lines that match with Homer's lays:
Such power this maid of nineteen years displays.
—*Anon.*, "*Greek Anthology,*" *Collins.*

Shelley claims that his song "drooped," but certainly those notes in which he sounds his lament soar into the rarefied atmosphere of high excellence, where the fluttering wings of an ephemeral insect keep them far above the plains of mediocrity.

As a far taper fades with fading night,
As a brief insect dies with dying day,
My song, its pinions disarrayed of might,
Drooped:
—*Shelley*, "*Ode to Liberty,*" *XIX.*

THE TEACHER

Throughout the ages, the voice of the reformer, whether emanating from the throat of poet or priest, prophet or king, or arising in a chorus from the people, has reiterated Solomon's admonition: "Go to the ant, thou sluggard; consider her ways, and be wise."[61] Lacking the harshness of the Hebrew man of wisdom, one hears a voice from the "Old English Miscellany" exhorting, "Let us imitate, then, this little creature, and on doomsday we shall not have cause for sorrow."

In a fable of gentle tone but unmistakable intent, Aesop tells the story of the futile attempt of the grasshopper to divert the ant from her labors by an invitation to chat. In the winter the grasshopper, dying of hunger, has learned too late that "It is best to prepare for the days of necessity."

Allan Ramsay completely overthrows the *status quo* of the ant, making her the flippant offender, priding herself upon being "made wi' better grace" than the clumsy caterpillar that she disdains as "some experiment o' Nature." When next they chance to meet the caterpillar has become a butterfly and proffers to the ant the following bit of advice:

Inferiors ne'er too much despise,
For fortune may gie sic a turn,
To raise aboon ye what ye scorn:
For instance, now I spread my wing
In air, while you're a creeping thing.
—*Allan Ramsay*, "*The Caterpillar and the Ant.*"

O. Henry, with a daring irreverence for her traditionary position, mocks the ant as a "silly creature," lacking judgment and discretionary power and merely following blindly an established custom, not departing from the beaten track enough to avoid an obstacle.

The ant by no means monopolizes the attention of the reformer. In Bacon's essay "Of Vain-Glory" occurs the pertinent statement: "It was prettily devised of Aesop: The fly sat upon the axle-tree of the chariot wheel, and said, 'What a dust do I raise!'" Though attributed to Aesop, this story occurs in the "Fables of Laurentius Abstemius." The bald man, usually a stock subject for humorists in his painful attempts to swat the bothersome fly, sometimes becomes a wiser man, evoking admiration rather than ridicule. Such a man disregards the fly when he returns to the attack, and, with the stoicism of a Spartan hero, is able to philosophize: "You will only injure yourself if you take notice of despicable enemies."

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[61] Proverbs, VI: 6.

In his "Essay on Man" Pope makes a very comprehensive summary of the evils of mankind, and is correspondingly inclusive in the remedies he prescribes.

Go, from the creatures thy instructions take:

. . . . .

Thy arts of building from the bee receive;
Learn of the mole to plough, the worm to weave;

. . . . .

Here too all forms of social union find,
And hence let Reason late instruct mankind.
Here subterranean works and cities see;
There towns aërial on the waving tree;
Learn each small people's genius, policies,
The ants' republic, and the realm of bees;
How those in common all their wealth bestow,
And anarchy without confusion know;
And these for ever, tho' a monarch reign,
Their sep'rate cells and properties maintain,
Mark what unvaried laws preserve each state,
Laws wise as Nature, and as fix'd as Fate.

Pope was probably influenced in his recommendations by the famous passage of Shakespeare, in which he commends the government of the bees:

. . . Therefore doth heaven divide
The state of man in divers functions,
Setting endeavour in continual motion;
To which is fixed, as an aim or butt,
Obedience: for so work the honey bees;
Creatures that, by a rule in nature, teach
The act of order to a peopled kingdom.
They have a king, and officers of sorts:
Where some, like magistrates, correct at home;
Others, like merchants, venture trade abroad;
Others, like soldiers, armed in their stings,
Make boot upon the summer's velvet buds;
Which pillage they with merry march bring home
To the tent-royal of their emperor:
Who, busied, in his majesty, surveys
The singing masons building roofs of gold;
The civil citizens kneading up the honey;
The poor mechanic porters crowding in
Their heavy burdens at his narrow gate;
The sad-ey'd justice, with his surly hum,
    Delivering o'er to executors pale
    The lazy yawning drone.
—*Shakespeare, "Henry V," I: 2.*

The insects have proved themselves such successful teachers that many of their lessons have become a part of the general knowledge of the people, who learn them as proverbs to govern their conduct. The people learn not only from the wisdom of insects but profit by the example of their folly. Bees with their complex social life have supplied a greater variety of precepts and axioms than any other insect.

The adage, "What's good for the bee is good for the hive," or stated negatively, "What is not good for the bee is not good for the hive,"[62] seems to indicate that long ago the bees settled the question of individualism versus socialism.

Men, with perseverance, might be included in the company in which woman is placed when she is criticized as stubborn! "Swine, women, and bees can not be turned."[62]

Perhaps in an effort to remember the details of his bee culture, the apiarist learned proverbs as one attempts to recall the number of days in each month by repeating a rhyme.

A swarm of bees in May is worth a load of hay;
But a swarm in July is not worth a fly.
—*Benham, "Book of Quotations."*

For one bee wanting who will burn the hive?
—*Seuman O'Sullivan, "Virginibus Puerisque."*

When bees are old they yield no honey.
—*Benham, "Book of Quotations."*

"A dead bee maketh no honey" is placed in George Herbert's collection of "Outlandish Proverbs" and if it ever served a practical purpose, nothing remains to testify to its usefulness.

Many distinctly different lessons may be drawn from the fly.

'Tis eminence makes envy rise,
As fairest fruits attract the flies.
—*Swift, "To De. Delaney."*

The fly that sips treacle is lost in the sweets.
—*Gay, "Beggar's Opera."*

Dead flies cause the ointment of the apothecary to send forth a stinking savour: so doth a little

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[62] Benham, "Book of Quotations."

> folly him that is in reputation for wisdom and honour.
>
> —*Ecclesiastes, 10: 1.*

Some version of the Eastern proverb, "You will catch more flies with a spoonful of honey than with a cask of vinegar," occurs in most languages.

Suggestive of Solomon's lesson of the "lilies of the field" is:

> Let me dress as fine as I will,
> Flies, worms, and flowers exceed me still.
>
> —*I. Watts, "Against Pride."*

Teaching temperance, is the advice: "Hast thou found honey? Eat so much as is sufficient for thee, lest thou be filled therewith, and vomit it."[63]

To the statement, "Haste makes waste," there is the proverbial exception which in the Russian language becomes "Hurry is good only for catching flies,"[64] or in another proverb "Nothing in haste but catching fleas,"[64] and in the Italian, which lengthens the list, "Nothing is done well in haste except running from the plague and quarrels, and catching fleas."[64]

The familiar desire to "kill two birds with one stone" is also rendered "kill two flies with one flap."[64]

Expressing opposite situations are the axioms: "To a boiling pot flies come not"[65] and "As worms are bred in a stagnant pool, so are evil thoughts in idleness."[64] Likewise, "Flies are busiest about lean horses."[64]

Sharing the popularity of proverbs are the aphoristic expressions descriptive of temper. "A fly has stung you"[64] when you are piqued; when you are wrathful you are as "mad as a hornet." The severity of the sting of the wasp or the hornet renders the adage to "stir up a hornet's nest" or to "put one's hand into a wasp nest" equally forceful in expressing troublesome, perplexing situations. When a man has an idea "He has a bee in his bonnet lug,"[66] and when he has a hint, he "has a flea in his ear."

Sad but all too true are the following conclusions of the sages:

> Ants never make for empty storehouses; no friend makes his way toward ruined fortunes.
>
> —*Ovid, "Tristia," Bk. 1: 9.*

> What the reason of the ant laboriously drags into a heap, the wind of accident will collect in one breath.
>
> —*Schiller, "Fiesco," II: 4.*

> You must lose a fly to catch a trout.
>
> —*Benham, "Quotations."*

> Fiddlers' dogs and flies come to the feast unasked.
>
> —*Benham, "Quotations."*

The recurrence of a proverbial expression and its adaption to very different ideas in literature may be illustrated by the following quotations, based upon the well-known adage, "Tread on a worm and it will turn." (In the Latin the same idea is rendered, "Even the fly has a spleen," or in the Greek, "Even the ant and the worm have their wrath.")

> . . . Never one
> Humbled himself before, as I have done—
> Even the instinctive worm on which we tread
> Turns, though it wound not—then with prostrate head
> Sinks in the dust and writhes like me—and dies.
>
> —*Shelley, "Julian and Maddalo."*

> Who 'scapes the lurking serpent's mortal sting?
> Not he that sets his foot upon her back.
> The smallest worm will turn, being trodden on.
>
> —*Shakespeare, "Henry VI," Part III, II: 2.*

> Man spurns the worm, but pauses ere he wake
> The slumbering venom of the folded snake:
> The first may turn, but not avenge the blow;
> The last expires, but leaves no living foe.
>
> —*Byron, "Corsair," Canto 1.*

> I am all but sure my dagger was a feint
> Till the worm turn'd—not life shot up in blood,
> But death drawn in;—(looking at the vial) this was no feint.
>
> —*Tennyson, "Becket," IV: 2.*

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[63] Proverbs, 25: 16.

[64] Benham, "Book of Quotations."

[65] Herbert, "Jacula Prudentum."

[66] Lily, "Euphues or the Anatomy of Wit."

Though man has traveled along the path of civilization for many centuries from the time of Solomon, he is still admonished by the most famous exponents of the age to go to the insect for wisdom. Poor man has proved himself a dull pupil, but in extenuation of his reluctance to heed the voice of the reformer, the scientist is about to convince him that fundamentally his insect models, whether performing exemplary or foolish acts, in reality deserve neither praise nor blame, being but mechanical followers of instinctive impulses.

Though the poet may not continue to praise the morals of the ant or the policies of the bees, he may still send man to the insect that, whether artist or artisan, works with matchless skill. He still may learn from

. . . millions of spinning worms,
That in their green shops weave the smooth-haired silk,
—*Milton, "Comus."*

and from

. . . the black wasp's cunning way,
Mason of his walls of clay,
And the architectural plans
Of grey hornet artisans—
—*John Greenleaf Whittier, "The Barefoot Boy."*

Rivaling in efficiency man's most modern machinery, the wood borers drill holes into hard woods, or carve out a system of tunnels more complicated than the New York subways. If man could construct machinery on a scale suitable for his use, as efficient as that of these little models, he could burrow into the earth for hidden treasure, perfect national waterways and airways at a pace that would offset the many delays caused by the slowly moving wheels of his legislative machinery. Long years with their heavy toll of lives must pass before man develops a technic of flying comparable to that of the winged insect that may outstrip the most daring "stunt" flyer, jump without a parachute, and glide to a safe landing in any field.

THE SATIRIST

Goliath, with premature scorn, rings out the challenge to the enemy:

Bid any little flea ye have come forth
And wince at death upon my finger-nail!
—*De La Mare, "Goliath."*

David, volunteering, vanquishes the giant and thereupon is so highly praised that the jealousy of his king is aroused. David then proves himself to be not only an ingenious warrior but a clever diplomat, diverting Saul's attack by saying: "Now, therefore, let not my blood fall to the earth before the face of the Lord: for the king of Israel is come out to seek a flea as when one doth hunt a partridge in the mountains"—*I Samuel, 26: 20.*

Though engaging in the more gentle combat of hearts, a king becomes, in the eyes of an unsympathetic friend, a mere gnat.

O, what a scene of foolery I have seen,
Of sighs, of groans, of sorrow, and of teen!
O me, with what strict patience have I sat
To see a king transformed to a gnat!
—*Shakespeare, "Love's Labor's Lost," IV: 3.*

The flea does heavy service for the satirist, hopping to his aid when he is angry or disgusted with giant, king or coward. A mollycoddle is said to "have no more man's blood in's belly than will sup a flea."[67] The liver also becomes the seat of bravery. "If he were opened, and you find so much blood in his liver as will clog the foot of a flea, I'll eat the rest of the anatomy."[68]

With something of the air of a professional trainer intoning the accomplishments of his remarkable little performers, Shakespeare pompously recites:

That's a valiant flea that dare eat his breakfast on the lip of a lion.
—*Shakespeare, "Henry VIII," 6.*

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[67] Shakespeare, "Love's Labor's Lost," IV: 3.

[68] Shakespeare, "Twelfth Night," III: 2.

Pope, in his gallery of undesirables, derisively pronounced every one a worm. This large gallery, including types ranging from fops and beaux to misers and physicians, almost exhausts the poet's catalogue of worms.

The wrath of the poet is vented upon those who infringe upon his creations. Pope, in stinging phrases, denounces Sporus:

Next o'er his books his eyes began to roll,
In pleasing memory of all he stole,
How here he sipp'd, how there he plunder'd snug,
And suck'd all o'er, like an industrious bug.
—*Pope, "Dunciad," Bk. 1.*

The superparasitism of insects becomes analogous in the biting satire of Swift, to plagiarists, the thieves who in turn become victims of other thieves, among whom there is no honor.

So, naturalists observe, a flea
Has smaller fleas that on him prey;
And these have smaller still to bite 'em,
And so proceed *ad infinitum.*
Thus every poet in his kind
Is bit by him that comes behind.
—*Swift, "A Rhapsody."*

The insect is featured in satirization of style, as well as content of verse.

Now hints, like spawn, scarce quick in embryo lie,
How new-born nonsense first is taught to cry,
Maggots, half-form'd, in rhyme exactly meet,
And learn to crawl upon poetic feet.
—*Pope, "Dunciad," I: 61.*

Wolcot, joining in the chorus of those who decry the famous Dr. Samuel Johnson, designates his as a

. . . turgid style,
That gives an inch the importance of a mile,
Casts of manure a wagon-load around
To raise a simple daisy from the ground;
Uplifts the club of Hercules, for what?
To crush a butterfly or brain a gnat.
—*Wolcot, "On Dr. S. Johnson."*

Readers who are secretly pleased to see fleas and gnats jumping from one baffling writer to another, should not rejoice too soon. A stray insect, desiring a change of diet, may alight upon the stupid reader and take an ample bite. However, if an anesthesia of humor is applied, the victim can feel no stinging pain, though the operation be a great surgical feat. Burns administers an anesthetic when he discovers a copy of Shakespeare, "splendidly bound, but unread, and much worm-eaten."

Through and through th' inspir'd leaves,
Ye maggots, make your windings;
But oh! respect his lordship's taste,
And spare the golden bindings.
—*Burns, "The Book-Worms."*

SIMILE AND METAPHOR

Personal characteristics are well described in terms of insects. Hair "like the wild bee's honey,"[69] eyes "like glow-worms,"[70] and "fingers as busy as bees"[71] appear incongruous in the picture of a woman "nakid as a worme."[72] However, when each is viewed properly, the effect may be a lovely picture of a Saxon maiden's

. . . curls streaming flaxen-golden,
By the misted moonbeams kist,
Dispread their filmy floating silk
Like honey steeped in milk.
—*F. Thompson, "Sister Songs."*

The genius of the poet in selecting and combining appropriate ideas is nowhere more apparent than in the similes that add richness and beauty when fittingly chosen but distort and mar when misplaced.

Anatomically man, by a consolidation of poetic ideas, becomes a living insectary. The lover, who so adroitly changes himself into a bee, in the effusiveness of his ardor transforms hands that steal his honey into wasps.

O hateful hands to tear such loving words—
Injurious wasps! to feed on such sweet honey,
And kill the bees that yield it with your sting!
—*Shakespeare, "Two Gentlemen of Verona."*

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[69] Masefield, "Third Mate."
[70] Shakespeare, "Venus and Adonis."
[71] Wordsworth, "Farmer of Tilsbury Vale."
[72] Chaucer, "Romaunt of the Rose."

The smile, voice and face of the adventuress are "all subtle flies to trouble man the trout,"[73] but the eyes of a faithful maid are "wild brown bees"[74] stinging her lover with a charming opiate.

In humility the psalmist says, "I am a worm, and no man";[75] and Tennyson, in the despair engendered of civil strife, prays:

> Strike dead the whole weak race of venomous worms,
> That sting each other here in the dust;
> We are not worthy to live.
> —*Tennyson, "Maud," III.*

> But corrupt worms, the worthiest men.
> —*Donne, "A Fever."*

Those who live parasitically are generally denounced as drones robbing the producers, the bees, of their honey. Idle courtiers are "gilded flies,"[76] misers hoarding the wealth of the land are "drones that rob the bee of her honey."[77] With equal aptitude insurrectionists are termed "caterpillars of the commonwealth."[78] Drone, though the most common, is not the only insect appellation given the thief.

> In thy weak hive a wandering wasp hath crept,
> And suck'd the honey which thy chaste bee kept.
> —*Shakespeare, "Lucrece."*

Othello laments the probability of being left behind "a moth of peace"[79] when the war is raging, but those who enlist as soldiers become "mortal bugs o' the field."[80]

Bees, usually praised collectively and individually as an example for personal or national emulation, in at least one instance become synonymous with the undesirable citizens, who are a "scandalous hive of those wild bees."[81] In no case, however, are the drones regarded favorably. Poets of the future may come to the rescue of the drone in view of his defense by contemporary scientists who accord to him the important function of the propagation of the species.

People seeking favoritism from the great or basking in the reflected glory of the famous are aptly designated as flies "that ever swarm about—the highest heads."[82] The irony of these pseudo-hero worshippers is implied in Hamlet's pertinent injunction—"The great man down, you mark his favorite flies."[83]

When a flippant, frivolous, ornate, character, rather than one deliberately parasitic, is depicted, the butterfly supersedes the drone as a metaphor.

> A mere court butterfly,
> That flutters in the pageant of a monarch.
> —*Byron, "Sardanapalus," V: 1.*

> Fops are painted butterflies.
> —*Pope, "To Mr. John Moore."*

The sports world honors its champions by giving them insect names. Football, baseball and basketball teams have been cheered to victory by lusty insects, especially "Hornets" and "Yellow-jackets," flying from the vociferous tongues of thousands of grandstand fans.

Those who win their wings and fly as new adventurers into that element so long ruled only by insect and bird have a fondness for fancying themselves and their craft insects or birds. The English girl who christened her plane the "Gipsy Moth" and made the long flight to Australia revealed a poet's imagination as well as an adventurer's daring.

Many pleasing little studies in contrasts may be made to show the enormous versatility of insects. In a pledge of allegiance, soldiers promise to follow "like stinging bees in hottest summer's day."[84] If fate decrees failure instead of success, they flee "like insect tribes before the northern gale."[85]

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[73] Masefield, "Widow of Bye Street."
[74] F. Thompson, "Unto the Last."
[75] Psalms, 22: 6.
[76] Shelley, "Queen Mab."
[77] Shakespeare, "Pericles," II: 1.
[78] Shakespeare, "Richard II," II: 3.
[79] Shakespeare, "Othello," I: 3.
[80] Shakespeare, "Cymbeline," V: 3.
[81] Tennyson, "The Holy Grail."
[82] Tennyson, "Columbus."
[83] Shakespeare, "Hamlet," III, 2.

Dressed in colorful silks, people are as "rich as moths from dusk cocoons,"[86] or the poet, with "robe and wreath" cast off is "like the tattered wing of a musty moth."[87] As bedraggled finery is more forlorn than threadbare rags, so a rich moth with a "tattered wing" is a more striking example of an impoverished state than a nondescript shrivelled fly.

The poet may be as busy as the proverbial bee or as "weak as a rained-on bee."[88]

Alacrity and slowness of action are contrasted by insect motions. A man "with a lancet quick as flies"[89] darts to an encounter, or moments crawl "like last year's flies."[90]

Joy is like a "summer fly,"[91] but "as motthes in the shepes flees anoyeth to the clothes, and the smale wormes to the tree, right so anoyeth sorwe to the herte."[92]

"Sweet thoughts" swarm "as bees about their queen,"[93] but "restless thoughts" are like a swarm "of hornets armed."[94]

People in many situations are comparable to insects. An enormous crowd at a fair congregate "like blowflies to the roast,"[95] and the gatherings at a theater are "like ants on molehills" or "bees to hives."[96] The Biblical analogy finds similarity between the advancing hosts from the enemy camp who are "as grasshoppers for multitude," an impressive comparison suggestive not only of great numbers but of destructive forces reminiscent of the plague, sent by special dispensation of providence for their punishment. Multitudes of the enemy are variously described as being as numerous as the cankerworms, the locusts or the caterpillars.

While hosts are comparable to insect swarms, a solitary individual may be likened with striking effect to a single insect. The disconsolate "Tess of the D'Urbervilles" was "like a fly on a billiard table of indefinite length."

Rejoicing or sorrowing, man has been likened unto insects. The old chieftains of the Iliad, retelling tales of war, "like grasshoppers rejoice,"[97] and Longfellow refers to the same famed men as "chirping like grasshoppers."[98] Conrad in a masterful prose has attained poetic results in such images as that in which he fancies the "soul writhing in his body like an impaled worm," or as that of the tortured Lord Jim "Squirming like an impaled beetle."

By no means all insect appellations are employed in a derogatory sense. Frequently terms of highest praise are voiced in complimentary attributes of insects. The bee, as previously observed, is a general synonym for the worthy citizen. It also is widely used in reference to the individual. A woman of domestic type is praised as the rare "household honey-making bee, Man's help!"[99] As a tribute to a true but unrecognized poet, Browning says: "My star, God's glow-worm."[100] In an epilogue to his sister, Francis Thompson calls her

"Bird of the sun! the stars' wild honey-bee!"

Metaphorically varied types of people and things become insects. The situation is frequently reversed and insects are transformed into people, souls or even gods. The butterfly is entreated by Wordsworth to remain as the "historian" of his infancy. Butterflies may be "gay triflers"[101] or "pretty genii of the flow'rs."[102] Moths are "daughters of the air."[103] The bee is "nature's confectioner," the "almsmen of spring-bowers"[104] or, most charmingly a reincarnated god sipping the nectar of the rose.

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[84] Shakespeare, "T. Adron.," V: 1.
[85] Shelley, "Revolt in Islam."
[86] Tennyson, "The Princess."
[87] F. Thompson, "Judgment in Heaven."
[88] Torrence, "Eye-Witness."
[89] Masefield, "Everlasting Mercy."
[90] A. Lowell, "Bird and Tree."
[91] Wordsworth, "Mother's Return."
[92] Chaucer, "Tale of Melibeus."
[93] Tennyson, "The Princess."
[94] Milton, "Samson Agonistes."
[95] Masefield, "Widow in Bye Street."
[96] Dryden, From Ovid, "Art of Love."
[97] Homer, "Iliad," Pope, 3.
[98] Longfellow, "Morituri Salutamis."
[99] Tennyson, "Becket," V: 2.
[100] Browning, "Popularity."

When entrapped, man is easily regarded as an insect caught in a spider web. "With as little a web as this will I ensnare as great a fly as Cassio."[105] Jim, ensnared by his mistress' wiles, becomes "a fly in Anna's subtle weavings."[106] Vivien playfully indulged her fancy as she drew

> The vast and shaggy mantle of his beard
> Across her neck and bosom to her knee,
> And call'd herself a gilded summer fly
> Caught in a great old tyrant spider's web.
> —*Tennyson, "Merlin and Vivien."*

The worm is perhaps most frequently chosen for the expression of abstract qualities. The worm described as a clumsy, creeping thing proves himself one of the most versatile literary insects. Man, his life and passions, his sins and his eternal punishment are analogous to various kinds of worms. In distress a person is a "poor twisting worm."[107] The malicious are scorned by the knightly who are "wroth to be wroth at such a worm."[108] Man, the worm, during the whole of his life is subject to "error, the worm,"[109] and is "tettered with worms of fear."[110] If he frees himself from error, pride creeps in "and swells a haughty worm."[111] From his brief respite comes

> Pain, that has crawl'd from the corpse of
> Pleasure, a worm which writhes all day, and
> at night
> Stirs up again in the heart of the sleeper,
> And stings him back to the curse of the
> light;
> —*Tennyson, "Vastness," IX.*

Failing to attain his heart's desire, man has lasting regret.

> The worm, regret, will canker on
> And Time will turn him never.
> —*Henley, "Echoes."*

When he sins, man is gnawed by the "worm of conscience."[112] Finally the worm, death, conquers him. Though his body be devoured by worms, his soul, if consigned to hell, is eternally preyed upon by "Shame that stings sharpest of the worms in hell,"[113] and "giant worms of fire forever yawn."[114] If he is righteous, though "The mortal worm might make the sleep eternal,"[115] his soul will leave his body as a butterfly leaving the chrysalis, and dwell eternally in a place "where the charm'd worm of pain shall gnaw no more."[116]

Various political and military features of government furnish many occasions on which the poet may express his social or patriotic ideas, sometimes calling forth expressions of highest praise and again his most scathing denunciation. The insect flies more often into the latter. Politics, covering such an extensive area of corruption, include the bee, otherwise an object of emulation.

> But bees on flowers alighting, cease their hum,
> So, settling upon places Whigs grow dumb.
> —*Thomas Moore, "Corruption."*

Without losing any of its perspicacity, the statement of an ancient sage regarding laws might be repeated to-day. "One of the Seven was wont to say: That laws were like cobwebs; where the small flies were caught, and the great break through."—*Bacon, "Apothegms," No. 8.*

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[101] Heine, "Holland's Butterfly Book."
[102] Hood.
[103] Fontaine, "Moth Book."
[104] Keats, "Isabella," 13.
[105] Shakespeare, "Othello," II: 1.
[106] Masefield, "Widow in Bye Street."
[107] Watts, "Sincere Praise."
[108] Tennyson, "Geraint."
[109] Shelley, "Epipsychidion."
[110] De La Mare, "Gloria Mundi."
[111] Meredith, "Modern Love."
[112] Shakespeare, "Richard III," I: 3.
[113] Swinburne, "Marino Faliero."
[114] Shelley, "Revolt of Islam," 37.
[115] Shakespeare, "2 Henry VI," III: 2.
[116] Wordsworth, "Descriptive Sketches."

In "The Prophyce of Famine" Churchill laments the fact that

There webs were spread of more than common size,
And half-starved spiders prey'd on half-starved flies.

Burke, in a masterpiece of forensic discourse, features grasshoppers in his "Reflections on the Revolution in France."

> Because half-a-dozen grasshoppers under a fern make the field ring with their importunate chink, whilst thousands of great cattle reposed beneath the shadow of the British oak, chew the cud and are silent, prey do not imagine that those who make the noise are the only inhabitants of the field; that of course they are many in number; or that, after all, they are other than the little shrivelled, meagre, hopping, though loud and troublesome insects of the hour.

A few revolutionists are grasshoppers; the entire army of the enemy are "ant-born."

Fly then, ill-manner'd, to thy native land,
And there thy ant-born Myrmidons command.
—*Homer, "Iliad" Bk. 1.*

ATTITUDE

The general attitude of poets toward insects may be inferred from their treatment of them in poetry. Some poets, however, take the trouble to express a direct opinion. While insects are highly specialized in their work, they are just the opposite in their effect on people. Insects are chameleons changing their color to blend with the tones of the poet's mood. Insects which are exactly alike will be exalted by one, denounced by another, and even the same poet will characterize the same insect at one time as divine and at another as vile, depending upon the mood of the moment.

Man, naturally regarding all life from the anthropomorphic standpoint, is inclined to consider the insect good or evil as it affects him favorably or unfavorably. Those insects that delight his eye or those that commend themselves for their industry easily fit into favorable places in the poet's writings.

When insects appear in such numbers as to destroy crops or to constitute a plague of any kind, one hardly expects the altruistic attitude to predominate. Even then the sympathetic Shelley ("Sensitive Plant") says their intent "Although they did ill, was innocent."

Personal parasites, preying upon the body of an individual, would seemingly be the last to appeal to the sympathy of the poet. Bryant, however, shows an unusual willingness to heed the voice of a hungry mosquito.

Fair insect! that, with threadlike legs spread out,
  And blood-extracting bill and filmy wing,
Dost murmur, as thou slowly sail'st about,
  In pitiless ears full many a plaintive thing,
And tell how little our large veins would bleed,
  Would we but yield them to thy bitter need.

Certainly no more than cold hospitality could be expected of the poet who suddenly finds himself host to insect guests, that, uninvited, come to make a stay of doubtful length. When the poet's neighbor becomes host instead, it is easier to sympathize with the guests who are accorded no welcome at all. Burns, when he began talking "To a Louse" visiting a pretentious neighbor, apparently thinks the lowly guest should not have come to such a high place, but when he remembers the haughty airs of the neighbor he is secretly pleased that she is to be embarrassed by the arrival of a disreputable guest.

Ha! where ye gaun, ye crawlin' ferlie?
Your impudence protects you sairly:
I canna say but ye strunt rarely
  Owre gauze and lace:
Though faith, I fear ye dine but sparely
  On sic a place.

. . . . . .

Oh wad some power the giftie gie us
To see oursels as others see us!

It wad frae monie a blunder free us,
And foolish notion:
What airs in dress and gait wad lea'e us,
And even devotion!

The gadfly that stung Pegasus and brought the ambitious Bellerophon crashing to earth, is not the only insect that has circumvented man's journey to heaven. Even Wordsworth lost his temper when "tormented by the stings" of insects, and Michael spent the day "cursing the flies and heat."[117]

The fly, generally regarded as a pest, perhaps best illustrates the broad sympathies of the poets who can lose sight of their personality and identify themselves with the insect. Kindly, tolerant Uncle Toby released a fly he had caught with the words: "Go, poor devil, get thee gone! Why should I hurt thee? This world surely is wide enough to hold both thee and me."[118] Oldys, remembering the short life of the fly, thinks of his own fleeting existence, and in sympathy, as to a fellow creature, offers the invitation:

Busy, curious, thirsty fly,
Drink with me and drink as I!
Freely welcome to my cup,
Could'st thou sip and sip it up;
Make the most of life you may;
Life is short and wears away.
—*Wm. T. Oldys, "The Fly."*

Wordsworth, watching a fly as "Between life and death his blood freezes and thaws," is moved in pity to say:

Yet, God is my witness, thou small helpless thing!
Thy life I would gladly sustain
Till summer come up from the south, and with crowds
Of thy brethren a march thou shouldst sound through the clouds,
And back to the forests again!
—*Wordsworth, "A Plague."*

Many poets think little about the insect *per se*, but consider it only as related to their art. They perhaps have an incentive to use insects, similar to that of Izaak Walton, who, with a thoroughness characteristic of anything involved in the furtherance of his piscatorial art, learned the morphology and names of an extraordinary number of insects adapted for fishing. He glibly rattles off lists of names that would tax the resources of a skilled systematist.

> There are also divers other kinds of worms, which, for colour and shape, alter even as the ground out of which they are got; as the marsh-worm, the tag-tail, the flag-worm, the dock-worm, the oak-worm, the gilt-tail, the twachel or lob-worm, which of all others is the most excellent bait for a salmon.
> —*Izaak Walton, "The Compleat Angler."*

Walton has no scruples whatever in his treatment of insects, dismembering legs or wings with the impersonal attitude of a surgeon. Typical of his indifference to the suffering of the insects used as bait, is the statement: "—in May, June, and July, he (the chub) will bite at any fly, or at cherries,—or at beetles with their legs and wings cut off,—or at any kind of snail,—or at a black bee, that breeds in clay walls." The ruthlessness with which Walton sacrificed his bait, subjecting insects or frogs to an extenuated existence of acute suffering, brought down upon his venerable head the indignation of Byron, who says:

That quaint, old, cruel coxcomb, in his gullet
Should have a hook, and a small trout to pull it.
—*Byron, "Don Juan," Canto XIII.*

Walton, perhaps, should not be judged too harshly for sacrificing everything to his art. While complacently awaiting the bite of the fish, he drifts into a gentle and meditative mood in which he expresses the opinion that anglers are the lords of creation and that insects were especially created for their pleasure. He believes that anglers can not only exploit insects to better advantage but can enjoy them more thoroughly than any one without the pale.

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[117] Masefield, "The Daffodil Fields."

[118] Sterne, "Tristram Shandy," Vol. 11, Chap. 12.

And yet I will exercise your promised patience by saying a little of the Caterpillar, or the Palmer-fly or worm, that by them you may guess what a work it were in a discourse but to run over those very many flies, worms, and little living creatures with which the sun and summer adorn and beautify the river-banks and meadows, both for the recreation and contemplation of us Anglers: pleasures which, I think, myself enjoy more than any other man that is not of my profession.

De La Mare, assuming a position exactly opposite to that of Walton, attempts to view the world through the eyes of a fly. With characteristic charm and delicacy, he says:

How large unto the tiny fly
  Must little things appear.
A rosebud like a feather bed,
  Its prickle, like a spear;

A dewdrop like a looking-glass,
  A hair like golden wire;
The smallest grain of mustard-seed
  As fierce as coals of fire;

A loaf of bread, a lofty hill;
  A wasp, a cruel leopard,
And specks of salt as bright to see
  As lambkins to a shepherd.
—*De La Mare, "The Fly."*

The scientist suggests that a more accurate picture of the actual appearance of things to a fly might be given in a mosaic, their many tiny ocelli overcasting all things with the diagrammatic outlines of a mosaic into which pictures are fitted.

The physical suffering of insects is either dismissed as inconsequential or regarded as comparable to that of a human being. "Juggling Jerry" delineates the more general attitude.

I've murdered insects with mock thunder;
  Conscience, for that, in men don't quail.
—*Meredith, "Juggling Jerry."*

Pope expresses a very cynical attitude when he says:

Who but must laugh, the master when he sees,
A puny insect shiv'ring at a breeze!
—*Pope, "Moral Essay," IV.*

Shakespeare's broad sympathies include the beetle.

The sense of death is most in apprehension;
And the poor beetle, that we tread upon,
In corporal sufferance finds a pang as great
As when a giant dies.
—*Shakespeare, "Measure for Measure," III: 1.*

With tender compassion Christina Rossetti pleads:

Hurt no living thing:
Ladybird, nor butterfly,
Nor moth with dusty wing,
Nor cricket chirping cheerily,
Nor grasshopper so light of leap,
Nor dancing gnat, nor beetle fat,
Nor harmless worms that creep.
—*Holland, "Butterfly Book."*

Alvar expresses both sympathy and wonder.

You insect on the wall,
Which moves this way and that its hundred limbs,
Were it a toy of mere mechanic craft,
It were an infinitely curious thing!
But it has life, Ordonio! life! enjoyment!
And by the power of its miraculous will
Wields all the complex movements of its frame
Unerringly to pleasurable ends!
—*Coleridge, "Remorse," V: 1.*

Cowper definitely limits his circle of friends to those who share his sympathy for small life.

I would not enter on my list of friends,
(Though graced with polished manners and fine sense
Yet wanting sensibility) the man
Who needlessly sets foot upon a worm.
—*Cowper, "Winter Walk."*

In Richard Le Gallienne's "Ballade-Catalogue of Lovely Things" insects are supremely beautiful.

Imperial sunsets that in crimson blaze
  Along the hills, and, fairer still to me,
The fireflies dancing in a netted maze
  Woven of twilight and tranquillity;

. . . . .

Prince, not the gold bars of thy treasury,
  Not all thy jewelled sceptres, crowns and rings,
Are worth the honeycomb of the wild bee—
  So runs my catalogue of lovely things.

PHILOSOPHY

From time immemorial the insect has awakened in man the most profound thought of which he is capable.

> Feeble though the insect be,
> Allah speaks through that to thee!
> —*Oehlenschlaeger, "Aladdin's Lamp."*

Gray, observing the insects in spring, said:

> To Contemplation's sober eye
> Such is the race of man:
> —*Gray, "Ode on the Spring."*

The power of the "murmur of the vagrant bee" to start a train of philosophical thought is beautifully expressed in the lines:

> . . . a slender sound! yet hoary Time
> Doth to the Soul exalt it with the chime
> Of all his years;—a company
> Of ages coming, ages gone;
> . . . . .
> But every awful note in unison
> With that faint utterance.
> —*Wordsworth, "Vernal Ode," IV.*

The harmony and unity of all life, the theme perhaps best suited to the philosopher-poet, effectively include insects. As a part of the loveliness of nature are "The cricket's cry and Dante's dream."[119] The conception of all life as one "Vast chain of being"[120] usually embraces insects as being at the other extremity of the scale from man, probably because they are the smallest visible creatures for comparison.

The pagan belief in the existence of a soul in all life, something of the all-pervading, all-permeating power of the divine, is echoed in such lines as

> Yet not the meanest worm,
> That lurks in graves and fattens on the dead,
> Less shares thy eternal breath.
> —*Shelley, "Daemon of the World."*

And in—

> . . . a worm whose life may share
> A portion of the unapproachable.
> —*Shelley, "Sonnet to Byron."*

The greatness of a God who can create the largest as well as the smallest things is depicted in the striking contrasts in such quotations as—

> Gives lustre to an insect's wing,
> And wheels his throne upon the rolling worlds.
> —*Cowper, "The Task."*

And—

> Though frail as dust it meet thine eye,
> He form'd this gnat who built the sky.
> —*Montgomery, "Gnat."*

Sharing "eternal breath," the worm worships.

> The spirit of the worm beneath the sod
> In love and worship, blends itself with God.
> —*Shelley, "Epipsychidion."*

> And filled the meanest worm that crawls in dust
> with spirit, thought, and love;
> —*Shelley, "Queen Mab."*

Whether the poet regards Nature as a gentle mother or as a ruthless force, the insect is involved.

> Still do I that most fierce destruction see,—
> The Shark at savage prey,—the hawk at pounce,—
> The gentle Robin, like a Pard or Ounce,
> Ravening a worm,—Away, ye horrid moods!

> For nature is one with rapine, harm no preacher can heal;
> The Mayfly is torn by the swallow, the sparrow spear'd by the shrike,
> And the whole little wood where I sit is a world of plunder and prey.
> —*Tennyson, "Maud," IV.*

In a more consoling mood, Emerson, with a belief in the essential goodness of things, says,

> Fear, not, then, thou child infirm,
> There's no god dare wrong a worm.
> —*Emerson, "Compensation."*

Comparing his life, of immeasurably longer duration, to that of the ephemeral insects, man may acquire an inflated idea of his importance and his grasp of infinity.

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[119] John H. Wheelock, "Earth."
[120] Pope, "An Essay on Man."

So man, the moth, is not afraid, it seems,
To span Omnipotence, and measure might
That knows no measure, by the scanty rule
And standard of his own, that is to-day,
And is not ere to-morrow's sun go down.
—Cowper, "The Task." VI, 1: 211.

Man, with his finite limitations, may never pride himself upon comprehending infinity.

In the insect world, the generations come and go before man's eyes. He observes the hurry and flurry of the insects in the seriousness of their life, the cruelties, the hazards of their existence. However, when his thoughts take a more humble turn, he compares his life and its complexity of affairs with eons of time, with innumerable worlds.

Raving politics, never at rest—as this poor
earth's pale history runs,—
What is it all but a trouble of ants in the
gleam of a million million of suns?
—Tennyson, "Vastness."

The sun comes forth, and many reptiles spawn;
He sets, and each ephemeral insect then
Is gathered into death without a dawn.
—Shelley, "Adonais," 39.

Comparable to Solomon's feeling that "all is vanity" is Hamlet's morbid speculation on the futility of life.

Your worm is your only emperor for diet: we fat all creatures else to fat us, and we fat ourselves for maggots: your fat king and your lean beggar is but variable service,—two dishes, but to one table: that's the end.
—Shakespeare, "Hamlet," IV, 3.

The leveling influence of death, bringing all down in equal helplessness to dust, is expressed in the lines—

The great, the base, the coward, and the brave,
All food alike for worms, companions in the
grave.
—Lansdowne, "On Death."

The eternal mystery of the universe is suggested by a tiny insect.

So, from the mould,
Scarlet and gold
Many a Bulb will rise,
Hidden away cunningly
From sagacious eyes,
So, from cocoon
Many a Worm
Leap to Highland gay,
Peasants like me—
Peasants like thee,
Gaze perplexedly.
—Emily Dickinson, LII.

The lonely splendor of Anatares shines
Through the barred window, and an aphis
crawls
Among the letters and the lines.
Little he guesses what these letters are,
Nor I the meaning of the trembling Word
Written beyond us, star on star.
—"Meditation," "Best Poems, 1927."

Wordsworth, oppressed at the baffling mystery, exclaims:

O wretched Human-kind!—Until the mystery
Of all this world is solved, well may we envy
The worm, that, underneath a stone whose
weight
Would crush the lion's paw with mortal anguish,
Doth lodge, and feed, and coil, and sleep, in
safety.
—Wordsworth, "The Borderers."

The idea that life is not made up of unmixed blessings is well illustrated by the mixture of gall with honey. "But ay Fortune hath in hire hony galle."[121] Spenser, moodily believing that the evils of love outweigh its compensations, says:

True be it said whatever man it said
That love with gall and honey doth abound;
But if the one be with the other weighed,
For every dram of honey therein found
A pound of gall doth over it redound.
—Spenser, "Faerie Queene," IV.

Wherever his search lead him, the eternal mystery which man ever seeks to solve is just as securely hidden beneath the gauzy wings of the most ephemeral insect as in the ocean depths or on the most distant star.

Symbolism

The philosophical ideas suggested to our poets by their contemplation of insect life are perhaps but the modern expression of those religious ideas with which the insect has inspired man from the most ancient times. A cursory glance through the museums of the world reveals many insects still remaining as the sculptured symbols of religious cults. One naturally conjectures that these ideas, crystallized in stone, lived in the pages of literatures deeply buried under the dust of the ages. The ritual, supposedly elaborate, as befitting a pageantry-loving time, has sunk into oblivion. The blue bee hovering over the head of the ancient Vishnu, the 300 golden bees carved on an altar to the Persian sun-god, and the beetle head of the Egyptian Khepera indicate something of the universality of insects in worship.

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[121] Chaucer, "Boethius."

Khepera, worshipped as a symbol of self-existent being, is perhaps typical of many gods that were reverenced as provocative of religious ideas.

> The god Khepera has a beetle for his head. The scarabaeus is also called Khepera, by Egyptians. The Scarabaeus or Sacred Beetle symbolised divine, self-created power. The early Egyptians believed it had no female but deposited its generative seed in round pellets of earth which it rolled about by thrusting it backward as it moved, by means of the hind legs 'and this in imitation of the sun, which while it moves from West to East turns the heaven in the opposite way.' From this mysterious ball the beetle comes forth full of life after twenty-eight days of incubation by the moon. It was believed that the beetle was born anew from the egg which it alone had created, and thus it symbolised for the Egyptians self-existent being. It was so highly reverenced that the wings on the winged glove or sun disk—the sacred symbol of the deity—have been thought by some to represent the scarabaeus instead of the falcon.
>
> —*Werner, "Myths and Legends of Chian."*

A certain Egyptian divinity was supposed to dwell in Aphis, a bull, which could be identified by very unusual markings

> . . . a square white spot on the forehead, the figure of an eagle on the back, a white crescent on the right side, and the mark of a beetle under the tongue. When the bull died, the god was expected to take up its habitation in another bull with similar marks of identification. Strangely enough, the priests invariably succeeded in finding 'an animal with their extraordinary marks, and the happy event was immediately celebrated throughout Egypt.'
>
> —*White, "The Student's Mythology."*

The gods of insects were not always worshipped in a spirit of loving reverence, but sometimes in a spirit of awe and with propitiatory motives. The Egyptians doubtless had no love for Beelzebub, the god of the flies, but knelt to him with a prayer that he render flies less obnoxious. Unless they accorded this deity their worship, they feared that he would convert the flies, always a potential menace, into a loathsome reality. Some scholars advance the theory that they worshipped Khepera, not because of its religious symbolism of self-existent being, but because of the fact that the scarab destroyed the worms of the Nile.

The insect enters largely into universal worship, not always as a deity, but more often because of its association with things divine. The bee was engraved upon ancient tombs as a symbol of immortality. The Greeks, with a typical appreciation of the harmony of body and soul, carved, along the dark walls of the catacombs, the butterfly as the "soul's fair emblem,"[122] emblematic also of the Christian's conception of Easter.

Though rejecting all "heathen" gods, the Israelites retained the heathen belief that wisdom and inspiration came as a result of feeding upon honey. Isaiah advises:

> "Butter and honey shall he eat, that he may know to refuse the evil, and choose the good."
>
> —*Isaiah, 7: 15.*

Jonathan, contrary to his father's command, "put forth the end of the rod that was in his hand, and dipped it in an honeycomb, and put his hand to his mouth; and his eyes were enlightened.[123]

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[122] Coleridge, "Psyche."

In his "Hymn to Mercury" Shelley says that the three fates,

. . . Whilst they search out dooms,
They sit apart and feed on honeycombs.

They, having eaten the fresh honey, grow
Drunk with divine enthusiasm, and utter
With earnest willingness the truth they know;
But if deprived of that sweet food, they mutter
All plausible delusions;

Japan, while not worshipping them, reverently relegates fireflies to the realm of the blest as the ghosts of slain warriors, who by virtue of sacrificing their lives for their country win eternal bliss.

Many insects are symbolical, in a more restricted and provincial way, of some evil augmented locally by their superabundance. In New Jersey the mosquito, actually the most frequent cause of the loss of temper of the good citizens of that state, becomes symbolical of all the annoyances and petty tribulations that fall to the lot of man.

The cicada, appealing to some as annoyingly loquacious and to others as continuously melodious, has become the symbol of both garrulity and Apollo.

The bee has long been the symbol of prosperity. The promise of a land of plenty, a "land that floweth with milk and honey," helped the children of Israel to forget the flesh pots of Egypt and cheered them during long years of wandering in the wilderness. When hardships seemed well-nigh unbearable and they were on the verge of revolt, the words of the prophets reminding them of their ultimate reward, of the "land flowing with milk and honey" fell as a soothing balm on their troubled spirits.

Insects have been chosen as political as well as religious symbols. The dragon-fly in Japan is the emblem of victory and naturally finds a place in the literature of the country, especially that commemorating past successes and arousing patriotic fervor for fresh encounters.

As his emblem of sovereignty, Napoleon chose the bee, which he wore carved on his signet ring, the official seal of the realm.

With a penchant for forecasting events, similar to that of an astrologer reading a horoscope, Mizaldus interprets the worm in the oak-apple. "If you take an oak-apple from an oak tree, and open the same, and shall find a little worm there, which if it doth flye away, it signifieth wars; if it creeps, it betokens scarceness of corn; if it run about, then it foreshows the plague." Elsewhere we find: "The fly in the oak-apple is explained as denoting war; the spider, pestilence; the small worm, plenty."

AMBER

Insects formerly passed unnoted become through the influence of the poet objects of beauty and value. In the words of Browning,

. . . we're made so that we love
First when we see them painted, things we
  have passed
Perhaps a hundred times nor cared to see.
—*Browning, "Fra Lippo Lippi."*

The tiny gnat or the infinitestimal aphis, embalmed in the amber bead of poetic thought, becomes even more precious to mankind than those beads that fell from the tree of Phaeton to envelop the tiny ants that wandered beneath her shade. Equaling if not surpassing all other gems in the poet's box of jewels are his amber beads preserving in enduring beauty and freshness not only the most unpretentious little insect but the most colorful butterfly that wanders into his garden.

The rich, sweet nectar from his flowers of thought has crystallized into lustrous amber, a "more than royal tomb," enhancing the beauty of the encased insect. But if the insect receives an added beauty from its lustrous tomb, it in return gives form and color to an empty tomb. The poet's amber bead may be likened to the fly's ivory tomb.

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[123] 1 Samuel, 14: 27.

A golden Flie one shew'd to me,
Clos'd in a Box of Yvorie:
Where both seem'd proud; the Flie to have
His buriall in an yvory grave:
The yvorie tooke State to hold
A Corps as bright as burnisht gold.
One Fate had both; both equall Grace;
The Buried, and the Burying-place.
Nor Virgil's Gnat, to whom the Spring
All Flowers sent to 'is burying;
Nor Marshall's Bee, which in a Bead
Of Amber quick was buried;
Nor that fine Worme that do's interre
Her selfe i' th' silken Sepulchre;
Nor my rare Phil, that lately was
With Lillies Tomb'd up in a Glasse;
More honour had, than this same Flie;
Dead, and closed up in Yvorie.

—*Herrick*, "*Upon a Flie.*"

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MATERIAL CULTURE AND THE RACIAL MATRIX

By Dr. WALTER HOUGH

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MEN who handle large numbers of museum specimens from races in all parts of the world come to sense subtle differences and resemblances in the material. The specimens present certain criteria or stigmata left by the hands of the workman by which they usually may be at once classed as Asiatic, African, Australian, American, and the like. This critical faculty is constantly exercised on almost all the complex impedimenta of modern life by experts who do not require the legend "Made in Germany," "Made in Japan," as a guide.

The criteria mentioned, representing observed data, may be referable to racial traits and may cover whole continental areas.

It seems to be feasible, then, to present a theory of a racial matrix producing recognizable characteristics of art products. If so, the evidence of distinctive traits easily observable points to means of classifying the phenomena of art expression among different races. By art expression is meant the unconsciously produced residuum taken to be the impress of race. The word art also is used to comprise any product of handicraft however common as well as other phases of arts and art culminating in the esthetic.

Such traits may be either strongly unmistakable or softened out by the constant changes in racial history exactly like the phenomena encountered in racial admixtures considered in physical anthropology by which pure races have been eliminated. It remains to be seen whether something deeper and more ingrained does not survive what seem to be major changes mentioned above.

A racial matrix producing recognizable characteristics of art expressions may seem difficult of proof, but traits are observable, however, indicating an indefinite something inherent in these expressions. Doubtless this something is the possession of every individual, unconsciously delivered as part of self-expression, and for lack of better classification may be termed psychological, or even going back to certain as yet undiscovered fundamentals in biology that act as reagents of stimuli in the production and determining of forms.

Resemblances in arts and industries have been explained by the alleged law of stimulus, the idea being that the mind will always respond to the need, for instance, of a tool by creating it through a series of obscure interactions. Some such rule it may be conceded would perhaps obtain for the simple basic tools which result from fundamental impulses, but it is more than doubtful that the rule would apply to complex adaptations. A cocoanut stripped of its husk by manual effort may be broken by throwing it against a harder object, by bashing two nuts together, or by means of a hand stone, which by this use is immediately classed as a hammer—in this phase a tool closest to instinctive actions the world over. The hammer develops in its lower stages by a succession of such actions growing more complex till it reaches beyond the sphere of primary actions. Thus a hammer or other tools may be independently invented and indistinguishable from other hammers and tools. But at each step in advance the hammer takes on individuality, has received something from its maker which will terminate in giving the tool the impress of racial art.

The broad general subject presented for discussion is whether there is distinctive racial art. The discussion may bring out the philosophy of style in regard to the products of material culture.

Another phase of the question bearing on the theory of a racial matrix has been recently raised by Dr. C. B. Davenport, of the Carnegie Institution of Washington. The existence of certain mental racial traits is maintained by Dr. Davenport, and it is his belief that these are hereditary, descending from generation to generation with such factors as the color of the skin. By means of exact experimental work in the line of tests to bring out mental differences Dr. Davenport has been led to advance his thesis.

From the nature of the case there is doubt expressed as to the validity of tests applied by one man to another, hence these tests meet with little acceptance in determining racial differences in mental reactions. The application of tests giving obviously valuable results within races is conceded, but the tests applied by the man of one race to that of another are viewed critically both as to tests and results. Nevertheless, Dr. Davenport's conclusions are supported by the visual observation method on objects of material culture advanced in this paper. In one case the brain product or psychology is fluid, and in the other it is fixed.

Owing to the unequal spread of racial arts, peculiarities are stronger and may be better observed in certain lines of handiwork such as pottery, lacquer and other products that require a personal touch, and especially in drawings, paintings and modeling. In this sense racial art evidences become more vivid with the progress of culture, though it is contended that it is evident in every product turned out by man.

Incidentally it may be more than probable that the origins of phases of arts were the product of individuals endowed with unusual capabilities. This would explain the sudden appearance of arts without discoverable antecedents. Such phenomena, however, are more evident in somewhat advanced stages and flower in the highest civilization.

There is also little reason to believe that human art has a common genesis. On the contrary the phyla of art are as divergent as the phyla of the animal kingdom.

The vitality of racial art characteristics may be assumed from the facts presented. Art may be termed protean, yet in the changes recognizable in centers and nooks and corners over vast geographical areas there can be discerned a unity in fundamental pattern. It is manifest that developments will take place in certain lines. In the fine arts, major and minor, here portraiture will flourish and there sculpture, decoration will be modified by materials, as textiles or prepared or natural surfaces, by pigments and many other materials and processes leading to a great variety, local or wide-spread, yet the impress will be racial throughout the whole complex.

In the application of the theory of racial art, supposing that it has validity, certain conclusions are reached. If there is a recognized Asiatic art impress, for instance, may we not apply it to the test of the origin of the art of the Western Hemisphere, thus supplying an additional proof of the peopling of America from the old continent? Obviously the generalization that the American aborigines could only originate from Asiatic stems is the statement which appears to many as an incontrovertible fact of physical anthropology.

Whether racial art would survive the vast distribution of population in the environments of the New World and come true to race is subject to discussion. It also requires a discrimination of extraordinary keenness to see in the complex manifestations of the art instinct among the tribes from the Eskimo to the Fuegians. Possibly in less advanced tribes small traces would be apparent, while in the civilized tribes the fruition of their art brings it out strongly enough to suggest direct Asiatic contact. In such cases as the latter the suggestion comes forward that the requirements of a suitable environment have been met for racial art to come true to form. In this respect we have Maya art in the advance of these people coming to attain a marked Asiatic phase also observed in the highly civilized Asiatic groups. This would counteract the far-fetched assumption of direct Asiatic contact in Central America that has proven misleading to many students.

In this line it is not possible to predict what has entered from various sources into the development of the art of a given race or what profound changes may take place when trammels are unloosed in high civilization, as for instance, in Europe. America, however, shows in its civilizations an uninterrupted development that has worked out in established lines. Thus Middle American art reached a more distinctly Asiatic character than Peruvian art, yet both have the same racial impress.

In reference to the groups entering America from the Asiatic continent it may be surmised that the arrivals had something more than the mere food, shelter and minor arts complex. They had this trait under discussion, and its development in America with all its shades, which now admit of the classification into strongly marked areas of design, remained Asiatic.

It has long been recognized that what is perhaps loosely called national art affords interesting comparisons. An outstanding example is the variety in the pictures of Christ. These pictures are necessarily imaginative, but, being a wide-spread subject for painters and sculptors, are excellent material for a study of the individuality expressed in national and beyond this in racial terms.

Familiar examples are portraits by Italian, Spanish, French, Flemish, Dutch, English and German artists, not affected by knowledge of racial characteristics and all having the European impress.

An Indian potter of Tonalon, Mexico, was commissioned to make a miniature bust of President Grover Cleveland from a cut in *Harper's Weekly*. This bust, now in the United States National Museum, is a good example of the meticulous work of the Guadalajara school of potter artists, whose remarkable creations in fragile material should be world famed. The bust is recognizable at once as of Cleveland, but in every lineament a Mexican simulacrum of the president.

A Japanese employed by the Commercial Museum of Philadelphia as a sculptor produced figures of American Indians which were startling renditions of the Indian as a Japanese. It might be said that the sculptor saw the Indian in that way, but in reality underlying his concept was subconscious predilection forcing his product into a racial mould.

Another example that may be given of the fixity of racial art is the effect on art forms of calibrated units, as beads and textile stitches. With these fixed units a uniformity of product would seem to be inevitable. Yet even here enter racial factors. Thus a piece of Bagobo beadwork would be instantly detected among American Indian specimens and proclaimed foreign though both classes show Asiatic traits rather than African or other regional decoration.

An instance of the breaking away from the static art conditions which envelop the artist is noted among the aborigines. A Western Eskimo, as stated by Dr. W. H. Dall, the Alaskan explorer, took up of his own accord the carving of realistic figurines which he did with remarkable skill and fidelity, shown in specimens of his work in the U. S. National Museum. On account of his departure from Eskimo standards of conventional art this man was regarded by the tribe as an iconoclast and was punished with suspicion and ridicule. It is evident that there may be a return to nature for types not only by individual artists and craftsmen, but by larger groups of mankind, but these manifestations of revolt, however, are soon lost in the compelling force which determines racial fixity in art. In fact they never can break entirely away from these inherent tendencies.

Within racial art may be recognized concentrations of varying intensity that may be termed national, embracing a group of people within well-defined boundaries or covering an indefinite geographical area. Under this class also comes tribal art, in which a single group may show a distinctive style cultivated in isolation. This occurs rarely, the usual state being a group of tribes in an area showing at the boundary marginal diffusion tendencies in the art. Areal or environmental art is the obvious unit selected by the investigator for description and comparison.

In the last group are noticed local and period art, the former furnishing the type development generally used as the index of the whole areal phase. Period art refers to the stages of progress or decay which admit of characterization as schools. Within these schools arise climaxes of achievement standing out as finalities in certain lines. This brings art down to the expression of individuals who produce works of the highest merit and who furnish leadership.

In so complex a problem many indeterminate elements exist, that is, conditions presenting faint criteria scarcely useful in detecting racial art. Thus we may have pronounced styles, lukewarm or even neutral styles, depending upon primary impulse, opportunities and education.

The object of education in art is to acquire skill derived as a result of the training of the hand and mind and an acquaintance with the grammar of design. This represents philosophically the bodying forth of a symbolic world of art based like the physical world of science on measurements, but with a different aim termed beauty. Gradually by the use of the components of the arts of design the producer finally reaches an expression which is his style, perhaps becoming an intensely individual characteristic recognizable as belonging to his work.

In the attainment of individual style there may be several periods in each of which the style for the time being seems fixed, but for want of better expression the artist is seen in all these.

It is conceived that the process by which individual characteristics become fixed may in some way be connected with the development of racial characteristics of art. It can not be said, however, that racial genius is produced in the summary way used in the teaching of art. There are in both cases large areas of unknown factors lying beyond present knowledge that perhaps could explain why the arrangement of forms, spaces, plus something in the human makeup, produce beauty.

CHARTING THE SEA AND THE AIR

By Rear Admiral W. R. GHERARDI, U.S.N.
HYDROGRAPHER OF THE NAVY

CHARTS are the first requisite for navigation—whether it be the sea or the air. Ships without charts would be as much endangered as ships without rudders. This also holds true for aircraft engaged in long coastal or transoceanic flights. Charts are a vital necessity in the navigational equipment of the ship and of the airplane. They are the other brains, the silent comrade, needed by the pilot, may he be voyaging by air or by water. They are his second vision—his direction finder—his guide and counselor.

It is the work of the Hydrographic Office of the United States Navy to collect, digest, and to issue timely information to the seamen and airmen so as to afford them the greatest possible navigational safety. To furnish them the benefits of new discoveries in science pertaining to land and sea has been the incentive of the Naval Hydrographic Office since its founding in 1830.

The work of the Hydrographic Office involves taking into account scientific matters relating to the ocean and the air and their navigation. But before all else, charts must be accurate—reliable without a chance for doubt on the part of their user.

Great changes have been recorded since Leif Ericson sailed southerly seas only because there was less ice to check the progress or endanger the safety of his galley, and Columbus knew he had come to a country unknown only by the strangeness of the birds that were his first welcoming hosts in a new land. Since then science with its charts for directions, distances, dangers and depths has made travel by sea safe instead of haphazard.

Cartography, or chart making, had its beginning in early days, when man first began to venture on the water. These early charts consisted of the merest details and were confined to the shores bordering the Mediterranean Sea. We know that the maps of the Egyptians drawn on papyrus date from about 1300 B. C. The development of the chart may be traced through the ensuing centuries, changing with new discoveries and new methods of printing, engraving and lithography. The maps of the astronomer, Ptolemy, taken from the teachings of Marinus of Tyre, were in use for about fifteen hundred years, until the discoveries of Columbus dispelled the popular belief that the world was flat. During this period they crudely served their purpose and the maritime world of those days. In the sixteenth century a Flemish mathematician gave to the world the Mercator Chart, so called after his Latin name. The principles involved in this chart are those embodied in the charts mostly used by seamen to this day.

As civilization progressed, the mariner's travels took him farther from those known shores. He ventured from the Mediterranean Sea to the Atlantic, touched the north on the shores of the British Isles, groped eastward along the Red Sea and finally reached the southeast by the Indian Ocean. After the adoption of the mariner's compass and the discovery of America by Columbus, overseas exploration received a great impetus. The search for gold, for new lands, for conquest or development were incentives for overseas explorations. These adventurers of the late middle ages sailed a trackless ocean, and returned bringing strange tales and crude drawings of the seas and lands they found. It was that age of great imagination which stirred and started discoveries in science of the sea.

The evolution of the chart paralleled new discoveries in science.

To-day, the more a country develops its industries, the more it becomes dependent upon other nations of the world and, hence, the greater the development of its foreign trade.

To safeguard this shipping maritime nations have been active in their hydrographic surveys during the past century. It is only since the latter part of the past century that nautical charts of the different nations have become more or less standardized. As a result, the modern accurate chart of to-day is of comparatively recent origin. To further this standardization, the International Hydrographic Bureau at Monaco was established in 1919 by the maritime nations.

In the United States, the Naval Hydrographic Office is authorized by law to issue charts to the vessels of the United States Navy and Merchant Marine and is given the task of making original surveys of foreign waters and producing charts of the high seas, and of foreign waters. The task of charting the coasts of the United States and territorial waters is performed by the United States Coast and Geodetic Survey. America has done its share in the scientific work of charting the seas. The names of Wilkes and Maury, both of the United States Navy, are indelibly stamped on the pages of the hydrographic development of the world.

During the course of years, since the establishment of the Hydrographic Office, naval vessels have made surveys in Korea, China, Mexico, Central America, West Indies, Brazil, Uruguay, the North and South Atlantic, North and South Pacific, Indian Ocean and in the Great Lakes. From these expeditions large additions have been made to a broader knowledge of our globe.

In constructing a chart it is essential that it should be correct in its geographic position. The accurate determination of the latitude and longitude of the chart is of the utmost importance to the navigator who must be able to fix his exact position from it. Successive telegraphic longitude expeditions have been sent out at intervals since 1874 by the Hydrographic Office. Now the use of radio greatly simplifies the problem of fixing longitudes.

Each maritime nation is interested in the charting of its own coastal waters and those of its dependencies. Many of them have efficient and well-organized hydrographic offices as part of their naval establishments which carry out their own surveys and publish charts for the use of the seamen. This hydrographic information is exchanged between nations, and foreign government charts are utilized, and their information is incorporated in various charts and publications produced by the Naval Hydrographic Office. There are still great areas which are either unsurveyed or not sufficiently surveyed for modern requirements of our large deep draft ships. And again, well-surveyed coasts and harbors are constantly undergoing natural and artificial changes which must be corrected on the charts if safety of navigation is to be secured.

The Hydrographic Office is still carrying on surveys of the high seas and foreign coasts. At the present time there are three such expeditions surveying the coast of foreign territories whose governments are not equipped to do their own surveys. The U. S. S. *Nokomis* is surveying in Cuban waters, the *Hannibal* in Venezuela, and the *Fulton* is to continue a survey in the

Gulf of Panama, where the present charts of these localities, based on very old surveys, are reputed to be many miles out. Aircraft are used to assist these specially equipped vessels in their work by photographing the terrain preliminary to the ground work. Hydrographic surveying has adopted the latest methods and instruments which have become available to surveys ashore, afloat and in the air.

All charts are corrected to date of publication and are kept up to date until issued. They may be classified as general, coastal and harbor charts, and are supplemented by "Sailing Directions," "Notice to Mariners," giving corrections or added information, and other publications.

An activity of increasing importance for the Hydrographic Office is that of safeguarding aircraft in transoceanic or coastal flights.

To take care of this need, sets of air charts for the coasts of the United States, Mexico, Central America and the West Indies are now complete and being issued. There is a comprehensive charting program underway which embraces the entire coast of South America. A series of handbooks, air pilots, comparable to sailing directions of nautical charts, are now in the course of preparation.

Progress has gone on to-day, so that charts for navigation of the air are as important as those for navigation of the sea. The aviation chart has a different appearance from the nautical chart in that it is especially constructed to indicate prominently those features visible from the air and by which the aircraft pilot determines his position. They must also be of a size to be used in the restricted space of an airplane cockpit.

In our studies of the upper air it seems reasonable to predict that the aviator will eventually have charts that will point out to him air currents of the upper air as did Maury's Pilot Charts show the winds on the ocean's surface to the navigators of sailing vessels. Such well-known aviators as Lindbergh and Hawkes in their non-stop transcontinental flights flew at times at high altitudes to take advantage of the favorable effect of upper air currents when blowing in the direction they were heading.

The Hydrographic Office is now publishing monthly a Pilot Chart of the Upper Air for the North Atlantic and one for the North Pacific.

As was the case with nautical charts, when air commerce creates the demand, it is safe to predict these upper air charts will become of such importance to the aviator in long flights that they will be issued to cover all parts of the globe.

The United States Exploring Expedition of 1838 to 1842, headed by Lieutenant Wilkes, was the first scientific expedition to leave the shores of the United States fitted out and provided for by an Act of Congress. It was the outstanding survey of its day and was created as a result of popular sentiment that the United States should take a larger part in the scientific work for the advancement of navigation and commerce. From those days to these, the Hydrographic Office of the Navy has progressed and kept pace with the needs of our complex civilization with regard to navigation and hydrography of the sea and of air. Great opportunities lie before it, and if the past be a test by which the future can be gauged, these opportunities will be realized.

THE THIRST OF PLANTS[1]

By Dr. D. T. MacDOUGAL
CARNEGIE INSTITUTION OF WASHINGTON, DESERT LABORATORY, TUCSON, ARIZONA

THE fundamental thirst of living matter, especially in plants, as expressed by wilting of crops, failure of forage and direct needs of domestic animals and of man himself, has incited inter-tribal conflicts, has laid the foundation of wars between peoples, and has been the cause of racial migrations affecting civilization in the profoundest manner. The water problems of a city of over a million people in one state have recently led to the expropriation and assignment of the water of one of our largest rivers, and a controversial discussion by the people of seven states occupying an area of half a million square miles. It is highly probable that among the earliest agreements between family or tribal groups were those as to the shared use of limited supplies of water; agreements that may well have constituted the beginnings of an important section of human laws. Although living substance may contain 99 per cent. or more of water, yet plants are forever thirsty, and when active, continually take in and lose water.

The growing substance in tender root-tips, in swelling buds, in the fragile wood-forming cambium layer of tree trunks, and in enlarging fruits, may have as much as a hundred or a hundred-and-fifty parts of water to one of solid matter, but as the liquid is being lost all the time a continuous new supply is necessary. An understanding of this condition is possible only on the basis of a comprehension of the ultimate structure of the living substance or protoplasm, which is far beyond the resolving power of the microscope.

The matter may be illustrated by filling a drinking glass loosely with excelsior or wood-fiber packing, then pouring in water until it rises up to the brim. So water is placed among the ultimate strands or particles of protoplasm, which—unlike the wood fibers—adhere by their poles like fragments of magnetized iron. These molecular clumps, or strands, unlike the wood fibers, also bind the water in much the same manner as they hold to each other, so that it does not run out freely: when the water is forced out by pressure the fine meshwork or grouping of the molecules is broken up and the protoplasm is injured or destroyed.

If instead of pressure the water should be slowly evaporated from the surface of the mass of living matter, the fibers would be brought closer together with an accompanying concentration of the sap which slows down the activities which constitute life. This is the universal effect of thirst.

Crop plants and forest and fruit trees obtain their water-supply from layers of soil of varying depths. The roots of some species form great webbed sheets of wide extent just underneath the surface. Others send rootlets deep into the sub-stream. The first habit is especially prevalent in places where the rainfall is used as soon as it soaks into the ground. Deeply penetrating roots are suitable for tapping ground water. The amounts of water these root-systems must take up is illustrated by the citation of the fact that a common sunflower with a spread of leaves of a total area of about 11 square yards will evaporate about a quart of water as vapor from its leaves in a day, and 75 quarts in the course of its development. A corn plant takes up about 16 quarts of water during its lifetime; a hemp plant twice as much. An acre of cabbage plants needs over two million quarts of water in a season. Two hundred beech trees on an acre require nearly double this amount. One of these trees loses about 80 quarts of water as vapor daily from its leaves. An acre of oat plants throws a million quarts of water as vapor into the air while maturing.

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[1] A radio talk presented under the auspices of the National Research Council.

Irrigation practice must put enough water into the soil to replace losses from leaves, and losses from the surface of the soil as well as the amount actually used or bound in the tissues. The farmer knows that over 600 pounds of water must be put into the soil to produce one pound of dry alfalfa, while the forester estimates that half a ton is necessary to make a pound of wood.

The plant is not simply a mass of jelly which soaks up water from below and loses it from upper exposed surfaces. It is a complicated living mechanism, a converter of the energy of sunlight into power. Some of this energy is used in making chemical compounds: but 98 per cent. of the energy absorbed by leaves and other green expanses of the plant is used in evaporating water from the surfaces of the cells. The work of lifting water from the rootlets deep in the soil to the crown of tall trees, to heights as great as 400 feet, is done by power generated in this manner.

This movement of liquid in the ascent of sap is as important as is the circulation of our blood. The movement in plants is not a circulation, however. Watery solutions rise from the roots to the leaves where most of the liquid goes into the air as water vapor. Only a small fraction of the water which moves rapidly upwardly in the woody conduits of stems is bound or held in chemical combinations in the cells.

The plant as a sun-driven factory holds its green absorbing surfaces so that the rays of light will be advantageously received and their energy effectively absorbed. Part of this mechanical function is accomplished by the concentration of stiff, rigid stems and branches of woody material. The firmness of the leaves and of all tender and fast growing parts is brought about, however, by another employment of water. In explanation of which it may be said that the living matter of plants is in the form of small units, protoplasts or cells, the elastic walls of which are capable of being stretched to as much as half their length like the walls of a toy balloon.

The living balloons have a layer of jelly on the insides of the cellulose walls. Water instead of air is pulled through the walls and lining layers of jelly with a force which may exert a pressure of a ton to a square inch. A stem, a leaf or a flower, the cells of which are distended by such pressures, will have great rigidity and firmness.

Production of sugars and other organic substances in green leaves depends directly on the extent of green surfaces exposed to light. Over-extension of the surfaces will be followed by undue loss of water which weakens this pressure and results in wilting. A maple, oak or pine tree may form leaves with a total area from a half to two acres. The loss of water from such extended surfaces is very large and hundreds of kinds of structural devices have been perfected by plants which regulate and control evaporation from leaves. The covering layer or epidermis may be dense, waxy or water-proofed to prevent useless loss of water. Then there are present numerous openings or stomata controlled by guard cells which act like valves. When these are open evaporation of water takes place as if the waterproof epidermis were removed: closed, the loss is negligible.

Water has been the major factor affecting the evolutionary development of all vegetation. No more striking illustration of the effects of water requirements on the form of plants can be cited than is afforded by the twelve hundred kinds of cacti inhabiting North and South America. Such plants absorb great quantities of water in a rainy season which can be used in dry times. A tree cactus may hold many hundreds of gallons of surplus water. Many plants in the arid regions of Arizona and Sonora have now a water supply laid in which would keep them alive until 1933 or 1934. A vine of the squash family, native to Sonora, stores water in an expanded base in such quantity that individuals have been known to live for fifteen years on their reserves.

The skilful use of the water supply, based upon a comprehension of the part it plays in living matter, is fundamental to intelligent agriculture and its dependent industries. Descriptions of the known features of use and storage of water by plants would fill many volumes. Enough has been said, however, to make it evident that life is where water flows; and that living matter is largely made up of water which is continually being lost, so that plants are forever thirsty.

THE EXTIRPATION OF ONE BUTTERFLY BY ANOTHER

By AUSTIN H. CLARK
U. S. NATIONAL MUSEUM

How is it possible for one kind of butterfly to extirpate a closely related kind? There is no question that this actually happens, for since the introduction of the European cabbage butterfly (*Pieris rapæ*) into North America we have seen the native gray-veined white (*Pieris napi oleracea*) entirely disappear from a large area formerly inhabited by it, while the checkered white (*Pieris protodice*) also has greatly decreased in numbers.

Observations recently made in the vicinity of Washington suggest a possible explanation of this interesting problem.

During the past four years the orange clover butterfly (*Colias eurytheme*), an intruder from the West, has enormously increased in numbers in the District of Columbia and the immediately adjacent region, and within the past two years the numbers of the native local species, the common yellow clover butterfly (*Colias philodice*), have not only relatively but actually decreased. The native yellow insect is becoming scarcer as the orange western form becomes more common.

The orange species is a stronger and much more active butterfly than the native yellow species, and wherever they are found together the differences between them are at once obvious and striking. Furthermore, when they are found together the males of the orange butterfly frequently are seen to annoy both sexes of the weaker yellow species.

Perhaps the most familiar of the butterflies that gather in little companies on mud in the late summer are the males of the yellow clover. These little companies of males represent individuals temporarily or permanently exiled from the fields through persecution at the time, immediately after the emergence from the pupa, when their chief interest in life is quiet and uninterrupted feeding. In other words, they are the victims of overcrowding in the home territory.

The orange males are never seen on mud—only in the fields. This species seems to be quite insensitive to overcrowding. Indeed, in portions of the West it becomes a more or less serious pest from time to time, and in some sections its caterpillars—known locally as "alfalfa worms"—do really serious damage.

From the known habits of these two clover butterflies we would infer that wherever they occurred together the yellow species would be affected by the males of the more active and stronger orange species more than it would by its own males, whereas the orange species would not in any way be affected by the yellow.

Thus overcrowding in the case of the yellow species would occur in proportion to the numbers of the males of the two species combined instead of merely in proportion to the numbers of the males of the yellow form alone. So with the increase in the numbers of the orange species the yellow would gradually decrease in numbers through the driving out from the breeding areas of the yellow males, and through the decrease in the number of successful matings as a result of the constant annoyance of both sexes.

This seems to be what is actually taking place. The strong and active orange species (*Colias eurytheme*) is causing a progressive diminution in the numbers of the weaker and less active yellow species (*Colias philodice*). It will be interesting to see whether the yellow species will be able to maintain itself in the face of the continued competition of the orange, or whether it will be reduced to insignificant numbers or even perhaps die out.

Years ago the checkered white (*Pieris protodice*) was very common in the District of Columbia and occasionally was more or less destructive to cultivated cabbages. It is a weaker and less active butterfly than the European white (*Pieris rapæ*) and is subject to persecution by it. The relations between the checkered and the European white are almost identical with those between the yellow and the orange clover butterflies. It is quite probable that the almost complete disappearance of the checkered white has been due mainly to constant persecution of both sexes by the males of its more active and more powerful competitor.

The disappearance of the gray-veined white (*Pieris napi oleracea*)—also a weaker and less active butterfly than the European white—from most of the territory formerly inhabited by it in the eastern United States may have been due to the same cause.

Incompatibility without direct competition seems to be causing the displacement of the yellow clover butterfly by the orange in the vicinity of Washington. The relations between these two very similar butterflies should be watched carefully from year to year. From observations on these insects we may learn something of much interest in the interrelationships of animal forms.

PHOTOMICROGRAPHY WITH ULTRA-VIOLET LIGHT

By A. P. H. TRIVELLI

THE EASTMAN KODAK COMPANY, ROCHESTER, N. Y.

In the second half of the nineteenth century Ernst Abbe laid the foundations for a new optical industry at Jena, Germany, which, under the guidance of his great scientific and executive ability, developed into an outstanding center of theoretical and practical optics. Abbe's famous work on the modern microscope is among the successful attempts to develop the knowledge of optics, and he determined the theoretical conditions required to reach the highest resolution with microscopic enlargements. Resolution, that is, the visibility of details, is determined by two factors: (1) it is proportional to the numerical aperture of the optical system, and (2) it is reversed in proportion to the wave-length of light used.

The aperture of the optical system does not in itself furnish a measure of the resolving power, but from Abbe's theory of the formation of microscopic images it follows that the sine of half the aperture angle supplies such a measure. For the ordinary optical systems the highest numerical aperture obtainable is nearly 1. In a microscope the object to be enlarged is placed on the stage between the condenser and the objective. The numerical aperture of the system can be increased by putting the object between condenser and objective in a homogeneous medium having a refractive index higher than that of air, that is, immersion oil. In such a system the numerical aperture is determined by the sine of half the aperture multiplied by the refractive index of the immersion liquid. With the introduction of the immersion method Abbe, using cedar oil, was able to increase the numerical aperture to 1.4. Czapski, using an immersion liquid of still higher refractive index, was able to increase the numerical aperture to 1.6. Objectives with such high numerical apertures, however, have practical disadvantages. The numerical aperture is also a measure of the power of penetration or depth of focus, which decreases with increasing numerical aperture. This makes it very difficult to get satisfactory results with Czapski's objective.

For most practical purposes a numerical aperture of 1.3 is sufficient and only in extreme cases are optical systems with a numerical aperture of 1.4 employed. About thirty years ago A. Köhler, of the scientific staff of the Zeiss works in Jena, increased the resolution of the microscope by introducing the use of ultra-violet radiation in combination with photography. The equipment was made available by the firm of Carl Zeiss, and while at first very little was done with the apparatus, in the able hands of F. F. Lucas, of the Bell Telephone Laboratories, it has proved to be of value for biological and histological investigations. Two objections were mainly responsible for the limited application of Köhler's method at first: the very high price of the apparatus, and difficulties in focusing. At the present time we have a number of institutions in the United States which can afford the expense of the Köhler outfit, and since laboratories are realizing more and more that for micrographic work of the first order skilled people with a scientific education are needed, Köhler's ultra-violet micrography opens greater possibilities of application.

The use of ultra-violet radiation in micrography is limited by its absorption. In general, radiations of wavelength shorter than 250 mμ (1 mμ, or millimicron, = one twenty-five millionth of an inch) are strongly absorbed by many objects so that micrography in this region becomes limited in its application. Ultra-violet micrography of wide usefulness must limit itself to the region between 400 and 250 mμ wavelength of radiation. Ordinary optical glass of every kind absorbs all ultra-violet wave-lengths shorter than about 300 mμ. This makes the usefulness of the region between 300 and 250 mμ wave-length possible only through the use of an optical medium, such as quartz, which transmits this radiation.

Von Rohr had already suggested the use of so-called monochromats—objectives which are corrected for only one wave-length of light. The characteristic feature of these objectives is that the rays are brought to a focus in a very perfect manner with respect to a specified wave-length, the combination being accordingly entirely devoid of chromatic correction. Furthermore, the system is made up of uncemented lenses, all of which may be composed of the same material. These objectives were used by Köhler in photomicrography with ultra-violet light. For the rest, success depends upon a monochromatic light source of high intensity. As the result of a systematic search Köhler found two useful light sources: the magnesium spark giving a line of 280 mμ wave-length, and the cadmium spark giving a line of 275 mμ wave-length, this line being 50 per cent. stronger than the other. To obtain the highest possible resolution an immersion liquid other than cedar oil had to be found. Cedar oil is too opaque for the ultra-violet. Glycerin was suitable, but its index of refraction necessitated placing the maximum numerical aperture of the quartz system at 1.25.

Oblique illumination doubles the resolving power. The extreme resolution of Köhler's photomicrographic outfit is 0.11 micron (1 micron = one twenty-five thousandth of an inch), which means that two lines separated from each other more than 0.11 micron will be visible on the negative and two lines separated from each other less than 0.11 micron will be reproduced as one single line. In ordinary microscopy in blue light of 450 mμ wave-length the maximum resolution with an optical system of numerical aperture 1.4 is 0.16 micron.

There is, in the near ultra-violet of the mercury-arc spectrum, a line of high intensity of 365 mμ wave-length, which can be isolated with a Wratten filter (No. 18A). In an optical system with a numerical aperture of 1.40 this radiation gives a maximum resolution of 0.13 micron. C. E. K. Mees pointed out that the difference between the resolution of 0.13 and 0.11 micron seems hardly sufficient justification for making the whole optical system of quartz with a complicated light source such as the condensed magnesium or cadmium spark, giving added trouble and expense, if nearly the same result could be obtained by an ordinary photomicrographic outfit, most optical glasses being probably transparent enough for 365 mμ wave-length radiation.

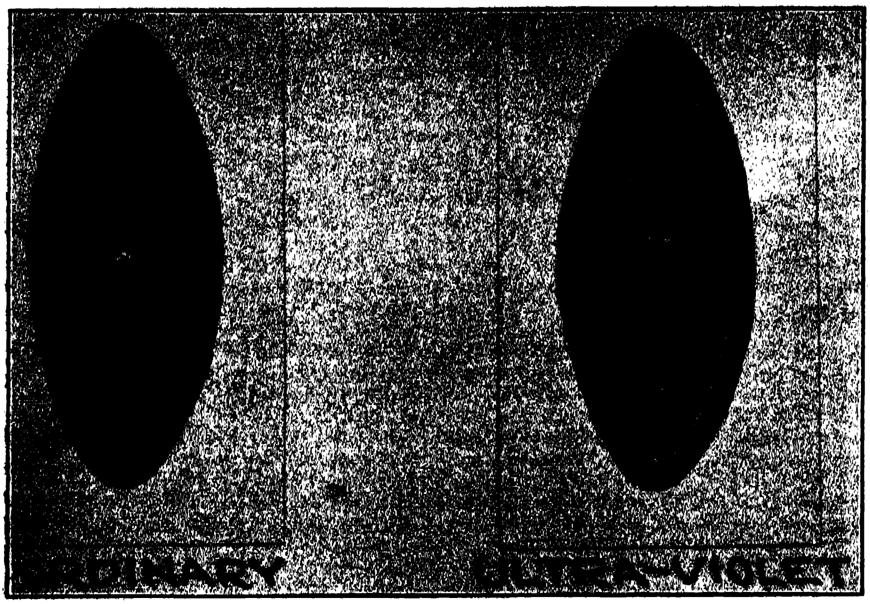
The possibility of such a practical application depends first of all on the transparency of the optical glass system. This was investigated by R. P. Loveland and the present writer with an ordinary semi-apochromat of 1.9 mm focal length, having the greatest thickness of glass of all achromatic microscope objectives. It was found that it is possible to get satisfactory short exposures even with the highest magnifications if a high intensity mercury arc is used. Such a lamp was obtained from Kelvin, Bottomley and Baird, Ltd., London. It operates at normal atmospheric pressure, using a 200-volt direct current starting with 4.4 amperes and, after the arc is formed, automatically continues at 2.2 amperes. Under these conditions we were able to obtain photographs magnified 1,000 and 2,000 diameters in a few minutes. As was to be expected, however, the results showed the necessity of specially corrected objectives to secure the full effect of the 365 mμ wave-length radiation.

The work was continued in collaboration with Mr. L. V. Foster, of the Scientific Bureau of Bausch and Lomb Optical Company. The 365 mμ mercury-arc line is a doublet lying near another doublet of 366 mμ wave-length. Since the application of such a non-monochromatic light source precludes the use of von Rohr's monochromats, we had to limit ourselves to objectives of the achromatic type, which bring two spectral colors together into the same focus. This suggested a focusing method in the near ultra-violet as easy and simple as one in the visible light. The objectives are made to bring the 546 mμ green mercury-arc line to the same focus as the 365 mμ wave-length radiation, so that achromatism is accomplished for one wave-length in the visible and for one wave-length in the invisible spectrum. For the isolation of the green mercury line Wratten filter No. 77, which transmits 72 per cent. of the light, is used. Thus, by using this filter, it is possible to examine visually the preparation to be photographed, and focus, after which filter 18A, which transmits 38 per cent. of the 365 mμ radiation, is substituted and the exposure made. The result is a perfectly sharp picture revealing detail invisible to the eye.

Sandalwood oil was found to be the best immersion medium for transmitting 365 mμ wave-length and having the proper optical properties. The distance between an oil immersion objective and the cover-glass of the preparation is about 0.2 mm. In this thickness cedar oil absorbs 56 per cent. and sandalwood oil 32 per cent. of the ultra-violet radiation. Since a requirement for full resolution of objects is that the condenser aperture must equal the aperture of the objective, the condenser must have immersion contact with the slide. This contact may require a layer of oil from 0.2 mm upward. Should the total thickness of oil used between the condenser and the slide and between the cover-glass and the objective be as great as 1.0 mm, the absorption by cedar oil at 365 mμ would be 98.4 per cent. and for the same thickness the absorption by sandalwood oil would be 85 per cent. The transmission for cedar oil would be 1.6 per cent. and for sandalwood oil 14.4 per cent.; that is, the latter would be nearly ten times as transparent for this radiation as cedar oil. It can easily be seen that whichever oil is used it is well to keep the thickness of the oil layer between the condenser and slide at a minimum.

Most objects are mounted in Canada balsam, and only in special cases is realgar or another medium used. Several of these substances are too opaque for the 365 mμ wave-length. A convenient and quick method by which to determine roughly the absorption of the balsam is by the use of an x-ray screen of barium platinocyanide, which gives a bright green fluorescence when exposed to 365 mμ radiation. In the beam of the ultra-violet radiation the slide forms a shadow on the x-ray screen if the balsam absorbs the radiation.

The great advantage in the use of slides having Canada balsam as mountant is that it is already used to a great extent in microscopic research work necessitating fixing and staining. Such



A PHOTOGRAPH DEMONSTRATING THE ADVANTAGES OF ULTRA-VIOLET LIGHT

Navicula, PHOTOGRAPHED IN GREEN LIGHT AND IN ULTRA-VIOLET WITH WAVE-LENGTH 365 mμ TO SHOW THE DIFFERENCES IN RESOLVING POWER. 450 ×. 16 MM OBJECTIVE FROM BAUSCH AND LOMB WITH 15 × HYPERPLANE EYEPIECE.

slides are useless for 275 mμ photomicrography, but very useful for 365 mμ photomicrography.

Very little is known concerning the absorption, in the ultra-violet, of the stains used in these slides. Mr. E. E. Richardson[1] determined their absorption spectra in 1 cm layer of solution, giving an approximate indication of what may be expected when a stain is used for ultra-violet photomicrography.

For the great majority of cases the Wratten M photographic plate is recommended for photomicrography. It is advisable in practice to employ the same photographic material as far as possible in order to reduce the number of variables to a minimum. A faster plate or film is preferable only with dark field illumination, very oblique illumination and with polarized light. The new Wratten hypersensitive panchromatic plate has a higher speed in visible light than the Eastman Speedway plate, and is, therefore, very suitable for photomicrography in such light. With 365 mμ radiation, however, the Speedway plate is about three times faster than the Wratten hypersensitive panchromatic plate and should be used for 365 mμ photomicrography in extreme cases of low intensity, mentioned above.

Photomicrography with radiation of 365 mμ wave-length makes available nearly a 20 per cent. increase of resolving power, or alternatively, if the resolving power obtained with visible light is sufficient, the use of ultra-violet enables an increase of depth to be obtained by reduction of the aperture. The effect of increase of resolution is specially noticeable when using high power oculars. For instance, at × 500 magnification with a 16 mm objective of numerical aperture 0.25 a sharp image could hardly be obtained with a × 20 magnifying eyepiece. Under exactly the same optical conditions 365 mμ radiation will give quite sharp images.

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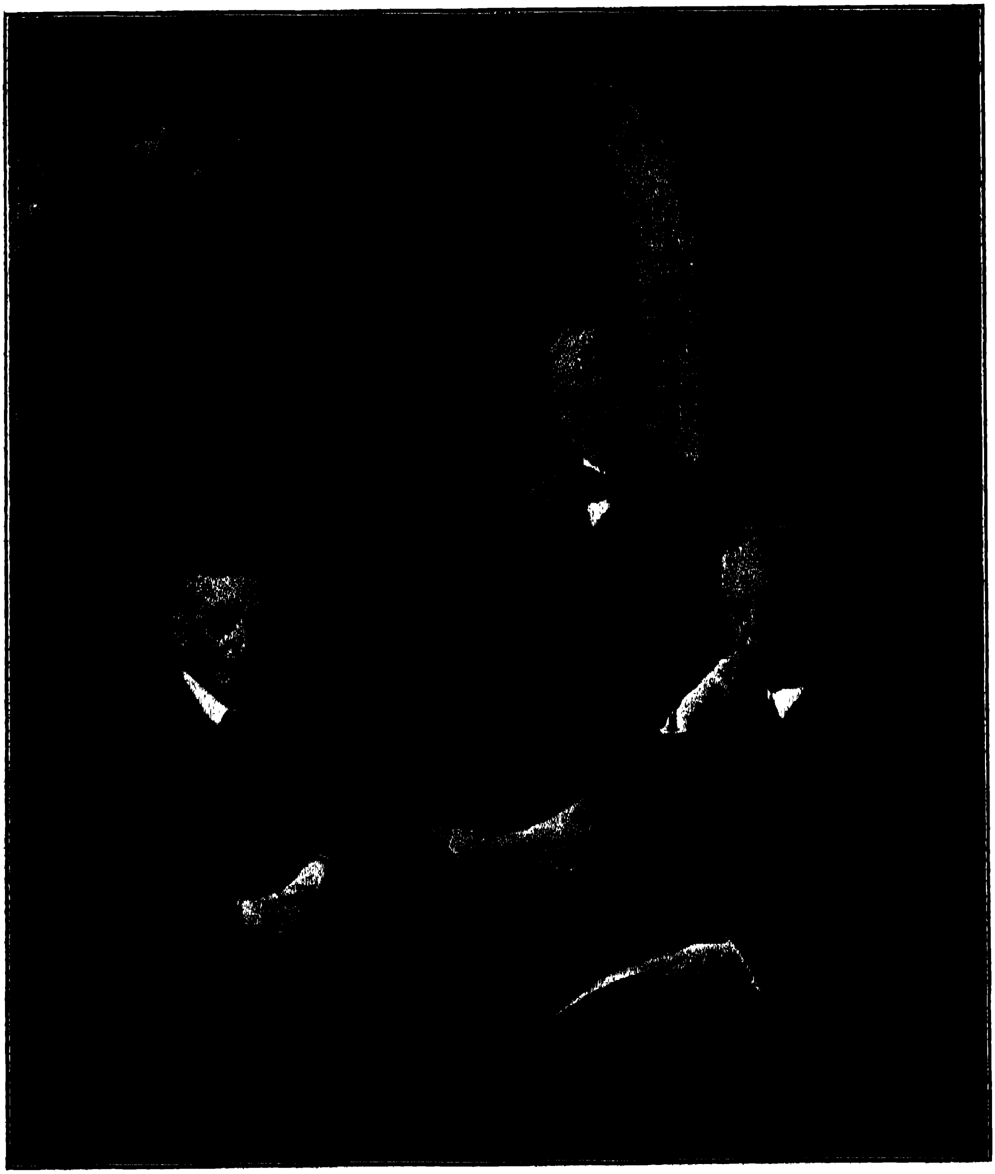
[1] Physics Department, Kodak Research Laboratories.

The greatest advantage of this radiation, in comparison with visible light, lies in the absorption differences pronouncedly shown by the different proteins. Köhler pointed out many years ago that one advantage of the ultra-violet microscope lay in the fact that with it organic specimens can be differentiated in structure by virtue of the selective absorption which they manifest toward ultra-violet radiation. In order to bring out in visual microscopy differences in biological specimens and histological structure it is necessary to stain the subject studied. In many cases study must be made of material in the living condition to avoid changes induced by fixation, and in such cases ultra-violet micrography should be employed. Unstained specimens may be observed by means of the ultra-violet micrograph much as though they were stained. There are, however, two requirements for such application: ultra-violet light itself must not be injurious to the organisms studied and the organism must, to a certain extent, be transparent to ultra-violet radiation.

In this respect Köhler's ultra-violet micrography is quite different from ultra-violet micrography with 365 mμ radiation. There are a great number of biological specimens which are absolutely opaque for 275 mμ radiation and which show differentiation in 365 mμ radiation, just as there are a great number of histological specimens which are perfectly transparent for 365 mμ radiation and which show differentiation in 275 mμ radiation. Both 275 mμ and 365 mμ radiations, therefore, have their own field of application.



Arthur A. Noyes Robert A. Millikan. George E. Hale

FOUNDERS OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY FROM THE PAINTING IN THE ATHENEUM BY SEYMOUR THOMAS

THE PROGRESS OF SCIENCE

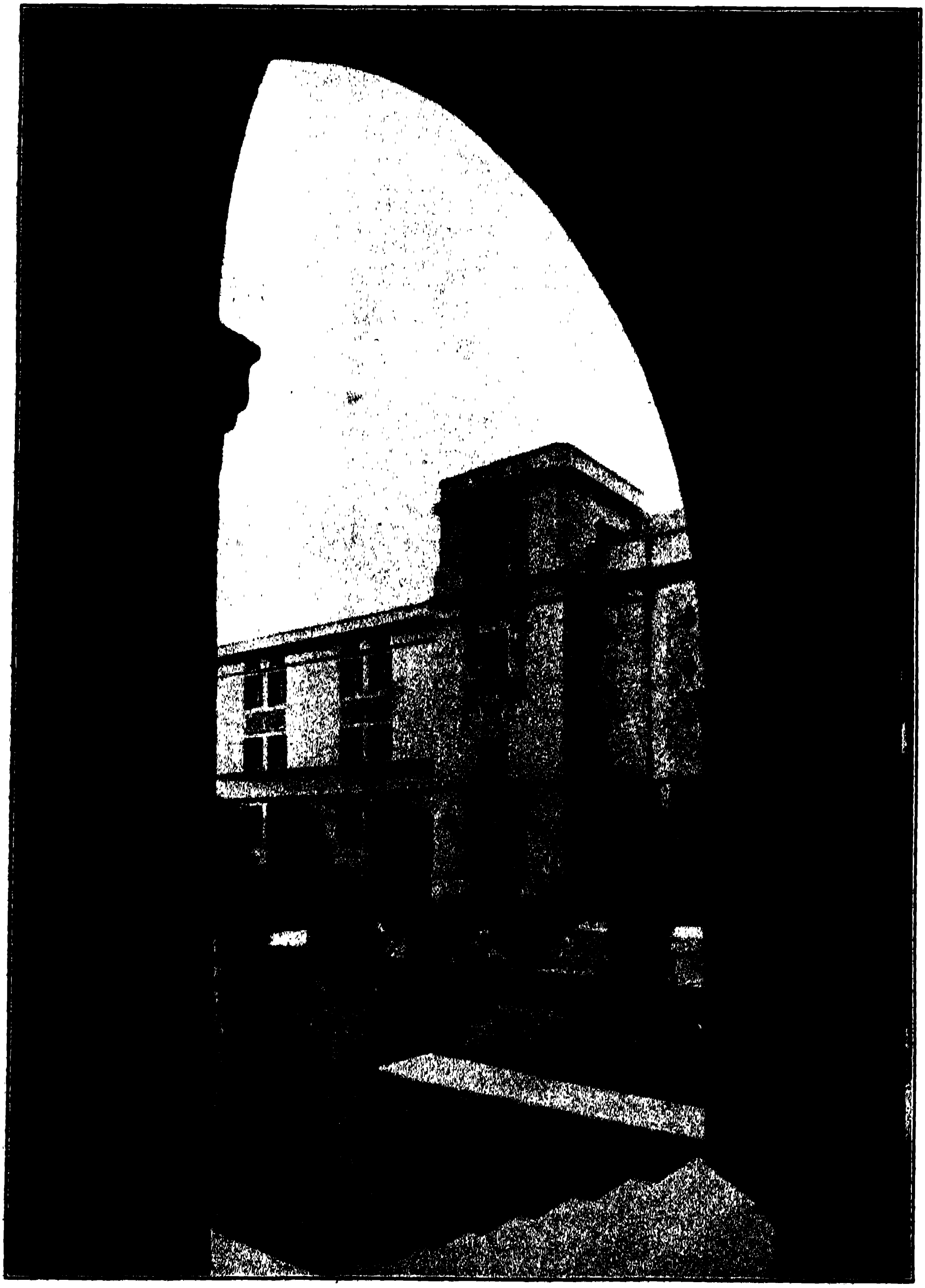
THE PASADENA MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE marked success of the eighty-eighth meeting of the American Association for the Advancement of Science—the first of the new series of national summer meetings—held in Pasadena and Los Angeles, California, from June 15 to 20, has apparently justified the association's new plan of holding annually, in addition to the winter meeting, a summer meeting of really national character. This success was due in part to the fact that the Pacific Division of the Association has for a number of years held very successful summer meetings on the Pacific Coast in which fifteen or more of the associated societies have regularly joined. The turning of this established convention into one of national character was therefore not difficult of accomplishment. All that was required was for the Pacific Division to withdraw temporarily, for the national officers actually to be present and to take charge, and for a goodly representation of Eastern members to attend.

All three of these requirements were successfully fulfilled. The officers of the Pacific Division very graciously retired in favor of the national officers while continuing to assist in every way possible in the details of arrangements and in coordinating the activities of the associated societies. The national president-elect, Dr. Franz Boas, attended the meeting at considerable personal sacrifice and gave one of the evening lectures which was an outstanding feature of the program. As Dr. Thomas Hunt Morgan, the retiring president, was already in Pasadena, both national presidents were in attendance, a precedent which the association will strive to follow in future summer meetings and which in itself gave a national aspect to the meeting. The representation from Eastern states and from foreign countries was much larger than had been expected and was also quite outstanding in personnel, national officers of the associated societies attending in many cases and contributing in a large way to the conduct of the program. The total attendance was nearly twice that at any preceding Pacific Division meeting.

A second reason for the very real success of the meeting was the nature of the program itself. Full accounts are being prepared by the permanent secretary of the association and will be published in an early issue of *Science;* nevertheless, it will perhaps be worth while to comment here upon the general success of the special features of the program inasmuch as they will undoubtedly set precedents for the conduct of future summer meetings.

The outstanding feature was unquestionably the large and unusually interesting group of special symposia and joint sessions with invited speakers. These covered a wide range of well-selected topics and were conducted by outstanding authorities in the various fields of science who in most cases had carefully coordinated their material. A unity which has often been lacking in the programs of the association was provided by making these symposia almost without exception joint sessions of two or more sections and their associated societies. This plan had the further advantage that the topics were treated



VIEW OF THE NORMAN BRIDGE LABORATORY OF PHYSICS

THE WILLIAM G. KERCKHOFF LABORATORIES OF THE BIOLOGICAL SCIENCES

from several view-points. Thus Dr. Boas suggested and arranged for a symposium on "The Antiquity of Man" with contributions by geologists, paleontologists and zoologists as well as anthropologists; and Dr. T. Wayland Vaughan, the president of the Pacific Division, planned and carried out a symposium on "The Major Problems of Modern Oceanographic Research," with four unusually well-selected papers and speakers dealing with the various physical, chemical, biological and geological aspects of the subject. At a joint session of the medical, biological and physical science groups, "High Voltage X-Ray Tubes and Their Medical and Biological Possibilities" were discussed. The engineering and geology sections held joint sessions on "The Colorado River Dam and Aqueduct" and on "Earthquakes and Earthquake Resisting Structures," as did the astronomy and physics groups on "The Present Status of the Problem of Nuclear Structure" and on certain astrophysical problems of common interest. The physicists and chemists united in a discussion of the "Quantum Mechanics of the Chemical Bond" and the chemists and biologists met together to consider various phases of "Photosynthesis and Photochemistry." These symposia were all of an exceedingly high caliber, and in more than one case literally every one in the world who had made important contributions to the subject was represented in the discussion.

The programs of the twenty-three associated societies which joined in the meeting were all excellent, many important scientific findings being announced for the first time, and the sessions were without exception well attended. Special mention should be made, however, of the interesting series of round table conferences carried out by the Pacific Coast Committee of the Social Science Research Council. Eight or ten such conferences on vital topics,

IN THE GROUNDS OF THE HENRY E. HUNTINGTON LIBRARY AND ART GALLERY

FROM LEFT TO RIGHT, DR. MAX FARRAND, DIRECTOR OF RESEARCH OF THE LIBRARY AND ART GALLERY; DR. J. MCKEEN CATTELL, CHAIRMAN OF THE EXECUTIVE COMMITTEE AND PAST PRESIDENT OF THE AMERICAN ASSOCIATION; PROFESSOR FRANZ BOAS, OF COLUMBIA UNIVERSITY, PRESIDENT OF THE ASSOCIATION; PROFESSOR THOMAS HUNT MORGAN, OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY, RETIRING PRESIDENT; DR. ROBERT A. MILLIKAN, OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY, WHO PRECEDED DR. MORGAN AS PRESIDENT.

DANIEL GUGGENHEIM AERONAUTICAL LABORATORY

with well-qualified leaders, were held simultaneously and often led to spirited discussions. The method might well be tried by other societies as a variant on the usual type of scientific session.

The plan of concentrating the scientific sessions into the mornings in order to leave the afternoons free for excursions, social contacts, discussions and recreation apparently met with the approval of the majority of those attending the meeting. The opening reception in the gardens of the Huntington Library and Art Gallery set a delightful precedent for future summer meetings, and the interest in the other social and entertainment features of the meeting was much greater than had been anticipated. The numbers availing themselves of the various excursions which had been arranged, the attendance upon the scientific exhibits, demonstrations and inspections and the good spirits of the participants gave hearty approval of these features. The only criticism of the program which was voiced was that it was too full and interesting to allow sufficient time for discussion and for the full enjoyment of the social features which were available. Future summer meetings may well provide more leisure for discussion and social recreation.

The third feature of the meeting—the popular evening lectures—also received the hearty endorsement of all attending the convention. These included the address already mentioned of the president-elect of the association, Dr. Franz Boas, on "Race and Progress," an experimental lecture by Dr. H. D. Arnold on "Science Listens," a lecture by Dr. Arthur L. Day on "The Present Status of Seismology," an address by Dr. Charles A. Beard on "Scientists and History," and an illustrated lecture by Dr. Edwin P. Hubble on "The Realm of Nebulae." All were exceedingly well presented and were well received, not only by the members of the association, but also by a large and interested popular audience.

E. C. Watson
California Institute of Technology

THE ATHENEUM

RESIDENCE HALL FOR VISITING PROFESSORS AND RESEARCH STUDENTS SERVING AS SOCIAL HEADQUARTERS FOR THE MEETING.

APPRECIATION OF THE PASADENA MEETING BY THE DIRECTOR OF THE PRESS SERVICE

INCREASED appreciation of—or perhaps it should be said admiration for—the enthusiastic energy and constructive ability of the scientific men of California was the outstanding impression made upon the minds of the members of the Association by the Pasadena meeting.

From every point of view it was a very successful meeting. Both in planning the meeting and in carrying out the plans the local committee did its work in a most efficient manner so that there was no confusion.

The meeting was officially opened by a reception given through the courtesy of the director and trustees of the Huntington Library and Art Gallery in the gardens of the Huntington estate which was attended by almost a thousand members and guests of the Association. Dr. Max Farrand, director of research at the Library, presided and welcomed the Association on behalf of the institutions which served as hosts—the Huntington Library and Art Gallery, the California Institute of Technology and the Mt. Wilson Observatory of the Carnegie Institution of Washington.

Brief talks were given by Dr. Thomas H. Morgan, Dr. Franz Boas and Dr. Robert A. Millikan, after which refreshments were served, and the members were invited to inspect the treasures of the library and art gallery and the magnificent gardens. Perhaps the most interesting feature of the gardens is the wonderful collection of cacti, including hundreds of different kinds of these bizarre and exclusively American plants.

The popular addresses given at the general session were unusually interesting and diversified. The speakers were Dr. Franz Boas, president of the Association, Dr. H. D. Arnold, Dr. Arthur L. Day, Dr. Charles A. Beard, Dr. Maurice Holland and Dr. Edwin P. Hubble. The attendance on the five evenings was about 1,000, between 1,000 and 1,100, 700, 500 and 500. Probably if the Greek theater at Los Angeles, where the evening address were given, had been nearer Pasadena the attendance would have been somewhat larger.

No single spot in the entire United States is so admirably adapted to serve as a center for excursions of most varied interest both by motor and by plane as is Pasadena. Taking advantage of this fact, the local committee arranged for no less than twenty-three excursions which were greatly appreciated and well attended.

The research exhibits were more numerous and varied than heretofore, and attracted much attention. One of the most popular and interesting was a representative collection of living reptiles from the southwestern states, including many different kinds of rattlesnakes.

Of the more strictly formal portion of the program, the arrangement of numerous symposia in many different fields of science was the outstanding feature. While it is difficult fairly to compare these symposia one with another, it is probably safe to say that the symposium on quantum mechanics and the chemical bond in which the three outstanding workers in that particular field, all very young men, participated, was the most significant.

The number of formal and informal papers presented was 538, distributed as follows: mathematics, 3; physics, 80; chemistry, 57; astronomy, 33; geology and geography (including oceanography and seismology), 36; zoology, 85; botany, 59; anthropology, 21; social and economic science, 64; engineering, 6; medical science, 66; agriculture, 20, and education, 16.

The subject matter in the papers was of an exceptionally high standard.

DABNEY HALL OF THE HUMANITIES

Many of the papers included entirely new material, while in many others a new light was brought to bear on subjects as yet not wholly clear. The proportion of papers written in plain and simple language was larger than at any previous meeting. The natural result of this was that the meeting received an unexpected amount of attention in the press, some of the eastern dailies reporting it more fully than they had reported the Cleveland meeting.

Of the papers presented twenty-three per cent. dealt with subjects concerning the Pacific states, while three per cent. dealt with subjects concerning regions beyond the borders of the continental United States, chiefly Hawaii.

In view of the altogether exceptional interest attaching to the geology, the fauna and the flora of the Pacific and the Mountain states, and to the oceanographic conditions along and off the Pacific coast, a much greater percentage of papers of local interest would have been anticipated. But especially within the past decade there has been a marked broadening in the American scientific outlook so that now although papers may be primarily based upon data gathered locally the broad application of the results brought out in any investigation are considered in their presentation.

The constant increase in the proportion of papers of broad general interest presented at the meetings of the association is bringing about a more clearly marked division of the scientific field, and is pointing out the way for a closer cooperation between the association and local academies and societies.

The total registration at the meeting was about 1,200, but there were probably about 1,500 in actual attendance.

Fully appreciative of the fact that the success of its meetings is directly proportionate to the energy displayed by the local committees in preparing for them, the association feels that it owes a debt of gratitude to the scientific men of California for making the somewhat experimental first regular summer meeting such a notable success.

Austin H. Clark

DR. L. O. HOWARD AND THE CAPPER AWARD

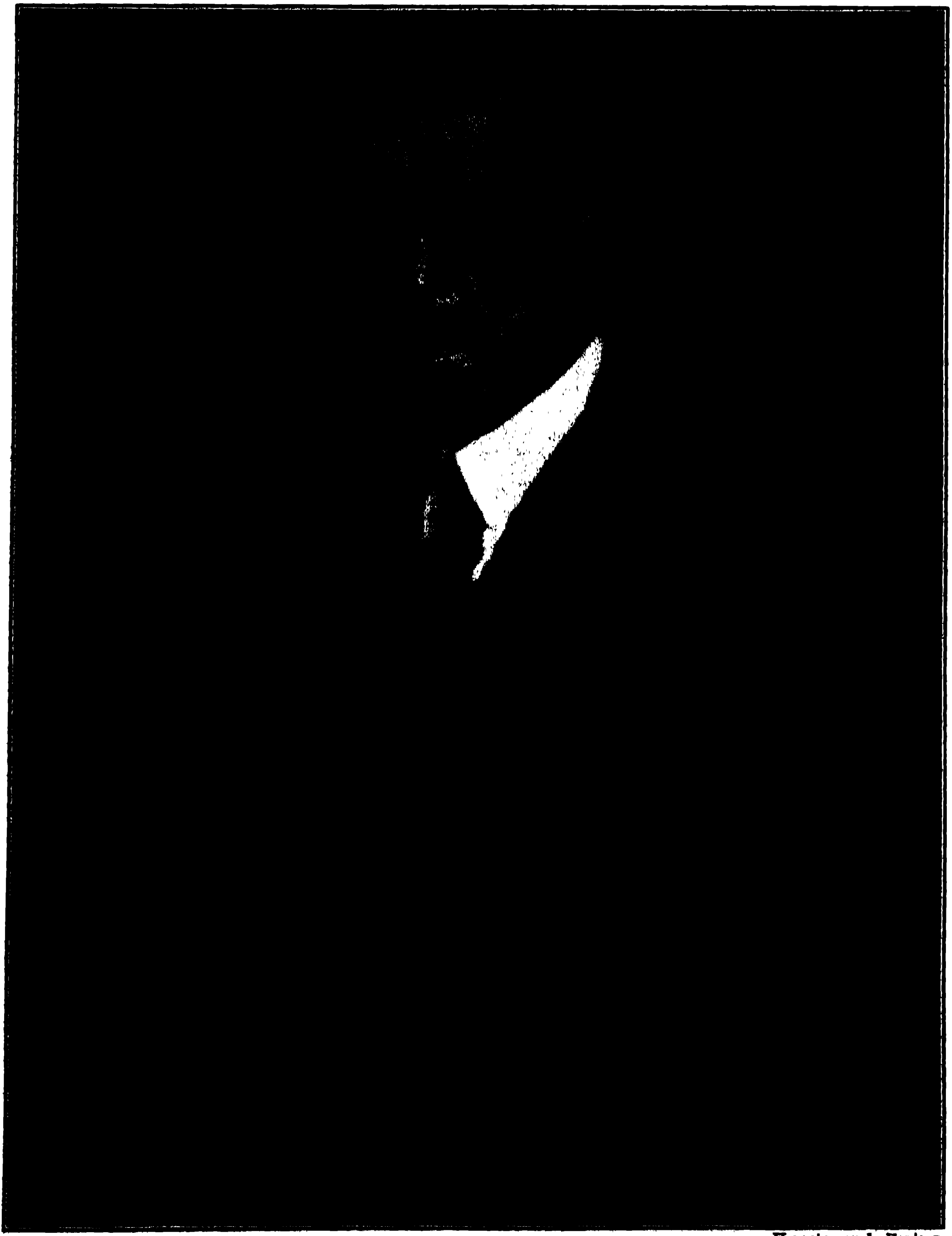
In the fall of 1878, a young graduate of Cornell University who had just attained his majority went with mingled feelings of wonder and enthusiasm to the city of Washington in response to a call from the United States Department of Agriculture. This young man had prepared at college for medicine but incidentally had become interested in entomology and had even pursued graduate study in that science. Therefore, when C. V. Riley, chief entomologist of the United States Department of Agriculture, applied to Professor J. H. Comstock for an office assistant, the latter recommended the young man in question who has since become familiar to all of us as Dr. L. O. Howard. What a happy combination of training, this medical preparatory work mingled with a study of the insect world; and how significant this intimate sympathy with the health of human individuals became in the later work of this able man.

To his disappointment, young Howard was employed at first simply as a clerk, but gradually, as matters developed, he was put at entomological work; and how enthusiastically he followed it. Not long ago in speaking of this period he said: "We were all young—it is surprising now to think how young we were! Trelease and I were 22, Mrs. Comstock was 25 and Comstock was only 30. We were filled with the enthusiasm of youth, worked hard and were delighted with the interesting and important discoveries we made." Thus early was set the stage for the work of a man in a field of scientific endeavor that ever accrued to the benefit of mankind.

Dr. Howard's earlier studies, which became particularly significant in his later work, were with the tiny hymenopterous parasites of scale insects. These studies not only led to his becoming a recognized authority on these minute insects but they undoubtedly impressed him with the importance of the rôle of parasites in checking the increase of insect pests. The trend of his thought in this direction was probably greatly accelerated and augmented by the success in the control of the cottony cushion scale in California through the introduction of the Australian ladybird.

No one plant or animal can long maintain the ascendancy over the other plants and animals on the earth. If one species increases abnormally for a time, it will eventually reach its height in numbers and then slowly or perhaps swiftly recede to its normal status. Such a phenomenon happens again and again in the insect world. Careful, extended studies by Howard, Tothill and others have shown that fluctuations in the population of an insect species are usually correlated with the scarcity and abundance of its natural enemies. Apparently, the sound, logical step to be taken in the ultimate, permanent control of an insect, especially an introduced pest, is to breed its natural enemies artificially and to distribute them throughout the range of the pest. Dr. Howard early realized the fundamental character of this natural control of insects and with the prescience of a forward-looking mind he organized and developed a program for the introduction and distribution of the natural enemies of the gipsy and brown-tail moths in New England on a scale never before conceived or attempted. The success attending this fruitful experiment led him to organize similar efforts at control in the case of other notable pests.

His remarkable work in the utilization of the natural enemies of insects in the control of injurious species has been the standard and inspiration for all similar work in this and in other countries. Unquestionably it stands as one of his notable contributions to the



—*Harris and Ewing*

DR. L. O. HOWARD

amelioration of the untoward conditions of agriculture in this country. No single idea at any time, however, has claimed all his attention. His was not a "single-track mind."

Dr. Howard had early been interested in mosquitoes and had early made a practical suggestion for their control although the use of oil on water was not original with him. His interest in mosquitoes had led him to ponder earnestly the early theory propounded by Dr. Carlos Finlay that these insects were responsible for the transfer of yellow fever from one human to another. The idea awakened and intensified his interest in the possible vital relations of common household insects to the welfare of man and kept him on the *qui vive* for possible developments. Later, in 1900, when the classic experiments of Reed, Carroll, Agramonte and Lazear demonstrated the intimate relation between the "Stegomyia" mosquito and yellow fever, Dr. Howard began in earnest his great work in educating all of us in the vital relations of insects to health. His extended studies on mosquitoes and the housefly, supplemented by his public lectures, timely articles, extended bulletins, and finally, his two books, "Mosquitoes; how they live; how they carry disease; how they are classified; how they may be destroyed" and "The Housefly, disease carrier," aroused the people of this country to the danger arising from close association with certain common insects. In the opinion of the writer this work of Dr. Howard constitutes another of his outstanding contributions to the welfare of the rural population of this country, for typhoid fever and malaria, at least, are distinctively rural diseases.

Granting that the tiny but innumerable animals we group together as insects are a constantly increasing and unrelenting menace to mankind and should be unceasingly fought with our most skillful methods, then Dr. Howard, of all men, has organized, developed and directed the greatest agency in the history of the science of entomology for carrying on the fight. For over thirty years he was chief of the Bureau of Entomology, and its present efficient organization is due to his far-sightedness, his skill as an organizer and his calm but forceful ability as an administrator. We believe his success as an administrator has come from his ability as a leader rather than from any quality he may have had as a driver. Dr. Howard early became national minded in his work as chief of the bureau. A little pamphlet entitled "Directory of Field Activities of the Bureau of Entomology," classified as Miscellaneous Publication No. 83 of the United States Department of Agriculture, Bureau of Entomology, speaks more eloquently than can the writer of the broad and extensive work in entomology developed by Dr. Howard. A superficial perusal of this tiny booklet will show that the Bureau of Entomology has established one or more field laboratories for the study of insect pests in every state of the Union with the possible exception of New Hampshire, Vermont and Minnesota. This evidence alone without further elaboration on the published results of the investigations carried on in these numerous laboratories attests the great work in the interests of agriculture performed by Dr. Howard. Perhaps after all, this direct service to agriculturists in the practical and effective solution of their problems in insect control will be considered his greatest contribution to the advance of agriculture in this country.

The writer can not close without emphasizing the internationally minded character of Dr. Howard. No man in this country has a wider, more intimate acquaintance with the entomologists of the world than has Dr. Howard. He has cultivated the acquaintance of these men not alone because of the ideas and suggestions that he might glean from them but that he might also render like service in return; and it is with a feeling of profound satisfaction that the writer is able to record the shipments of natural enemies of insects of this country by Dr. Howard to various foreign countries to aid the authorities in bringing insect pests of those localities under control.

Every individual in this country and the many in foreign countries who know Dr. Howard and are familiar with his work are not only gratified that he has received the Capper Award but are sure that it has been most deservedly bestowed.

GLENN W. HERRICK

CORNELL UNIVERSITY

THE CAPPER AWARD

MY object in establishing The Capper Award for Distinguished Service to American Agriculture was to provide a concrete expression of gratitude to some of the people who make contributions of national importance to American agriculture and to assist in stimulating public appreciation of unusually fine service to our basic industry. The award consists of a gold medal and $5,000 in cash, and is made annually.

The project is completely in charge of a committee of seven men: James T. Jardine, chief of the Office of Experiment Stations, United States Department of Agriculture; Carl R. Gray, president of the Union Pacific Railroad System; Dr. John H. Finley, editor of the New York *Times;* Dr. Walter T. Swingle, plant physiologist and agricultural explorer, United States Department of Agriculture; Dr. H. A. Morgan, president of the University of Tennessee; Alexander Legge, president of the International Harvester Company, and F. D. Farrell, president of the Kansas State College. F. B. Nichols, the managing editor of my farm papers, is secretary of the committee, and all correspondence concerning the award should be addressed to him at the Capper Building, Topeka, Kan.

It is made in accordance with five simple rules, as follows:

1. The award will consist of a gold medal and $5,000 in cash.
2. Any living American who has rendered distinguished service to the agriculture of the United States is eligible for consideration.
3. No time limit is imposed as to when the service rendered to agriculture was performed.
4. The award will be made annually.
5. No person who has received the award will be eligible to receive it again.

The first award, made in 1930, was given to Dr. S. M. Babcock, of the University of Wisconsin, in recognition of his epoch-making invention of the world-famous "Babcock Test" for butterfat and for his numerous other less widely known scientific contributions to the welfare of agriculture, and especially the dairy industry. Dr. L. O. Howard, former chief of the Bureau of Entomology of the United States Department of Agriculture, will receive the award of 1931, for his work in entomology, and especially for his efforts in the biological control of insects.

About 200 persons were nominated for the award last year, some by as many as 175 different individuals. Apparently this indicates a considerable interest in this project. It is my hope that this award will serve as a source of real inspiration for some of the younger men in agricultural work, in encouraging them to put forth their maximum efforts in the development of our basic industry. In any case I have been much gratified by the general approval which has been given to the two awards which have been made. As the project develops from year to year I hope we can continue in our selections to merit the commendation of the scientific world.

ARTHUR CAPPER

U. S. SENATE

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1931

SINANTHROPUS—PEKING MAN[1]

ITS DISCOVERY AND SIGNIFICANCE

By Professor G. ELLIOT SMITH
UNIVERSITY OF LONDON

In thanking the Harvey Society for the honor of being invited to give this address, I must also make open confession of the fact that I am breaking the high tradition of Harvey Lectures. For my distinguished predecessors in this office have given you in their respective lectures accounts of their own original investigations. My task on the present occasion is the humbler, though not less important one, of giving you an account of other men's investigations on the fossil remains of *Sinanthropus*, the Man of Sin (China), which I have recently been privileged to witness in Peking. In attempting to give you some idea of the impression made upon my mind during this mission of ancestor worship in China, I find it difficult, without using adjectives that seem extravagant, to express my feelings when I saw the remains of the most primitive member of the human family so far recovered. The accounts of the fossils given by Dr. Davidson Black in "Palaeontologia Sinica" and the "Bulletins of the Geological Society of China" were so strictly objective and written with admirable restraint and economy of comment that there was always at the back of my mind the possibility that the impression of the fossils and their meaning which I formed from reading these accounts might possibly have exaggerated their importance. The material, however, has proved to be even more impressive and significant than I had realized before I saw it. The Peking skull is certainly the most illuminating relic of early man. In this address I want to explain my reasons for this opinion and for regarding the work done in Peking during the last three years as marking a new epoch in the study of human paleontology.

The only two fossils of primitive members of the human family comparable in age with *Sinanthropus* are *Pithecanthropus*, found by Dr. Eugen Dubois in the bank of the Solo River of Central Java in 1891, and *Eoanthropus*, found near the village of Piltdown in Sussex by the late Mr. Charles Dawson in 1912. Both discoveries were due to the good fortune and insight of individual discoverers. Doubt and suspicion have been cast on both fossils ever since they were found and the lively controversies concerning their age, their nature and affinities have prevented any general agreement as to their real significance. Both were deposited in gravels or tufaceous material along with remains of extinct mammals of various geological ages, and the association of particular fossils with the human remains was an open question. Writing in *Science* of February 22, 1929, Professor Henry Fairfield Osborn discussed the difficult problems of the dates of the gravels in which the remains of *Pithecanthropus* and *Eoanthropus* were found. The Ape Man of Java was at first supposed to be Pliocene in age. Then opinion gradually changed, and most writers now assume from the evidence of the elephant-like fossils such as *Stegodon* that the gravels on the bank of the Solo River are Lower Pleistocene. Professors Dietrich, of Berlin, and Osborn, of New York, now regard the Proboscidean and other quadrupeds associated with *Pithecanthropus* as Middle Pleistocene, and the Ape Man as another instance of the survival of a very primitive type of mammal in a forest environment where food was plentiful and safety was assured by concealment or flight rather than by open competition with the use of weapons. If this opinion should be confirmed—and Mr. van Es, the geologist in charge of the survey of the Solo region, is now preparing an authoritative opinion on the question—then *Pithecanthropus* might prove to be the degenerate descendant of a more primitive weaponless form such as *Sinanthropus* seems to be.

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[1] Harvey Lecture delivered at the New York Academy of Medicine on December 4, 1930.

Professor Osborn suggests the possibility that Piltdown Man may be as old as the Pliocene. He claims that the dark-colored fragments of the skull of *Eoanthropus* were intermingled with similarly colored fragments of Proboscidean molars of unquestionable Upper Pliocene age belonging to *Archidiskodon planifrons* and *Anancus arvernensis*. As other tooth fragments (which, however, are lighter in color) belonging to a Lower Pleistocene hippopotamus are also present it is possible that *Eoanthropus* also may belong to the Lower Pleistocene. In the case of *Sinanthropus* there is no such uncertainty as to the contemporary fauna, for the human remains were left on the floor of a cave and a vast number of the animals which roamed the region of Chou Kou Tien in these remote times left their bones in the same cave. As all these fossils belong to the same geological epoch, the Lower Pleistocene, there can be no doubt of the age of *Sinanthropus*.

In Dr. J. Gunnar Andersson's preliminary report on the Chinese site Chou Kou Tien (in 1923) he was inclined to interpret the presence of fossil remains of a true horse and the absence of *Hipparion* as evidence of an Upper Pliocene age. As fresh material was collected and intensively studied in 1927 and 1928, however, it became possible definitely to determine the age as Early Pleistocene, or what Professor Grabau calls "Polycene." The laborious task of developing and studying the vertebrate fossils has been carried out in large measure by Dr. Chung-Chien Young, who was trained under Professor F. Broili in the University of Munich in association with the Nestor of Chinese paleontology, Professor Max Schlosser. Pére Teilhard de Chardin, in collaboration with Dr. Young, published a comprehensive survey of the evidence in the Bulletin of the Geological Society of China (1929), from which I quote a few sentences. Remains of more than fifty types of mammals. besides amphibia, reptiles and birds, were found. The most characteristic forms associated with *Sinanthropus* were the flat-antlered deer (*Euryceros*), a rhinoceros comparable to the species *sinensis*, *Hyaena sinensis*, and other interesting creatures such as a big beaver (*Trogontherium*) and the primitive buffalo (*Bubalus*). The paleontologists are agreed that the deposit is definitely older than the loess (Middle Pleistocene), which includes remains of *Rhinoceros tichorhinus*, *Hyaena crocuta*, *Cervus elaphus*, instead of the different species of the same genera at Chou Kou Tien. If the deposits in which *Sin-*

anthropus occur are thus shown to be definitely older than the Middle Pleistocene, the absence of truly archaic types, such as the big *Hipparion* and *Chalicotherium,* and the presence of modern types, such as *Equus,* indicate an age later than the Pliocene. The contents of the caves and fissures in the Ordovician limestone include breccia, gravel, sand and clay.

The question is repeatedly asked what number of years have elapsed since the end of the Pliocene period. This can not be answered with any degree of certainty. Recent researches on this problem have been clearly summarized by Dr. Chester A. Reeds in an article entitled "How Old is the Earth?" in *Natural History* (March–April 1931). Assuming the reality of Pliocene Man, Dr. Reeds suggests that the antiquity of man must be at least 1,500,000 years. Hence we may tentatively adopt the view that a million years represents the scale of time since the Man of Peking roamed the Western Hills. Although some few of the bones found in the deposits may have been introduced by flood-waters most of the bones have been left in the cave or brought in by animals which lived there in Early Pleistocene times. Pére Teilhard de Chardin and Dr. Young think there is reason to believe that the *Sinanthropus* family whose remains have been recovered actually lived in the Chou Kou Tien cave.

The discoveries in China have provided evidence to link together all three genera of Early Pleistocene men into a coherent and correlated series. They also confer upon the fossils from Java and Sussex a respectability that formerly was widely denied them. Moreover, the Man of Peking is a much more generalized and primitive type than the other two genera and the examination of his remains enables us to picture what the common ancestor of all three—the as yet hypothetical Pliocene Man—was like. For these, and other reasons to be explained later, the discoveries at Chou Kou Tien have a unique interest and significance. They establish a sure foundation upon which to build our conceptions of the earlier members of the human family.

THE CIRCUMSTANCES OF THE DISCOVERY

The history of the circumstances under which the fossil remains of man have been recovered is full of interest and not without importance. The finding of the remains of *Pithecanthropus* and *Eoanthropus* was due to brilliant individual achievements. The Chinese discoveries, on the other hand, were the result of a systematic search and organized team work extending over several years, in the course of which paleontologists of different nationalities followed up slight clues and thus were led on step by step to the culmination—at any rate for the present—of the discoveries in December, 1929.

For many years the museums of Europe and America have been obtaining fossils from China by purchasing "dragons' bones" from the druggists' shops in Peking and elsewhere. Some years ago Professor Max Schlosser ("Die Fossilen Säugethiere Chinas," Abhandl. d. bayerisch. Akad. d. Wissensch. Bd. XXII, 1903), summarizing the knowledge obtained by such means, referred to a fossilized tooth sent to him by Dr. Haberer from Peking. He suggested that it might possibly be that of a very early ape-like man or an exceptionally man-like ape, who might be as old as the Earliest Pleistocene or even the Pliocene period. As, however, nothing was known of its provenance or associations, it was not possible to estimate the full significance of this remarkable observation. His keen diagnosis was enough, however, to keep the

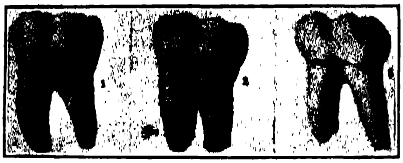

FIG. 1.[2] THE TOOTH WHICH IS THE TYPE OF *SINANTHROPUS PEKINENSIS* (2)

COMPARED WITH THE CORRESPONDING TOOTH (1) OF A MODERN CHILD AND THAT OF A YOUNG CHIMPANZEE (3).

minds of men of imagination alert and open for further discoveries of very primitive ape-like men in the Far East.

The inauguration of the National Geological Survey of China created the circumstances that led to the great discovery, which provides such complete confirmation of the possibility adumbrated in Professor Schlosser's brilliant argument.

When Dr. V. K. Ting, the director of the survey, invited Professor J. Gunnar Andersson, formerly director of the Swedish Geological Survey, to act as adviser, China secured the services of a paleontologist with a rare flair for the discovery of promising sites.

The primary object of the institution of the survey was the strictly economic business of gathering information concerning China's mineral resources. The work had not proceeded far, however, when the directors of the survey realized that they could not carry out this technical program in a way that was satisfactory either to the administrative authorities or to the industrial world without devoting attention also to purely scientific investigation. The study of fossils is of fundamental importance for the elucidation of the geology of the coal fields and of a variety of problems of economic importance. In 1920 the survey was fortunate in securing the cooperation of Dr. A. W. Grabau, formerly professor of paleontology in Columbia University, New York, whose knowledge of invertebrate fossils and broad outlook on the problems of geology have been one of the most important sources of inspiration and guidance of these developments in China.

The importance of the results which these investigations brought to light impressed upon Dr. Ting the need for adequate publication. Hence he instituted the series of memoirs, "Palaeontologia Sinica," in which the results were fully and promptly presented in a way that bears favorable comparison with the best publications in America and Europe.

The Geological Survey has become an important factor in the development of China's resources. Under the directorship of Dr. Wong Wen-hao, who succeeded Dr. Ting, the field work and the intensive research in the laboratories and museum have been continued and further developed.

In the year 1916 Dr. Andersson began his investigations of the Cenozoic deposits of north China and made large collections of fossil vertebrates, for the most part mammals. In the work of examining this material he cooperated with Professor Carl Wiman, of Upsala.

THE SITE OF THE DISCOVERIES

The Western Hills, forming the picturesque background to the palaces and temples of Peking, are the scene of the epoch-making discoveries with which I am concerned in this address. The interest of this range, famous for its natural beauties, is enhanced by the multitude of temples and other buildings scattered on its heights and in the recesses of its valleys. Throughout the history of Peking these hills have played an important part in the development of the city. For many centuries the builders of temples and palaces have obtained from the Western Hills the supply of beautiful white marble which lends distinction to the architecture of the former capital. Not only did the beauty of this material appeal to the esthetic interest of builders, but the Chinese name "white jade" conferred a sanctity and a magic virtue on this stone, which enormously enhanced its attractions. The builders also resorted to the Western Hills to obtain the limestone from which they get the lime needed for building operations. Hence the people of Peking are well acquainted with this beautiful resort and its petrological resources. About a quarter of a century ago the construction of a branch line from the Pekin-Hankow Railway at a point thirty miles southwest of Peking brought the railway to the village of Chou Kou Tien, to provide a means of transporting coal to Peking from the rich deposits near that village. The building of this railway line served other purposes, for it led to the development of the quarrying of limestone for lime-burning at Chou Kou Tien and thus was responsible for exposing the fossil beds where the remains of the *Sinanthropus* family were found.

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[2] For all the illustrations I am indebted to Dr. Davidson Black.

In the year 1919, when Dr. Andersson began work in the regions to which these circumstances had directed attention, he found a bone deposit at Chi ku Shan, a name with a meaning ("Chicken Bone Hill") which suggests that the Chinese were aware of the existence of the fossils. Two years later (1921), while excavating fossils on this site he overheard his workmen expressing surprise that he should be spending his time at Chi ku Shan when there was a much richer deposit of fossils nearby. This chance conversation first directed his attention to the site which has yielded such important material. He took the hint and transferred the scene of his excavations to Chou Kou Tien. When he was collecting the early Pleis-

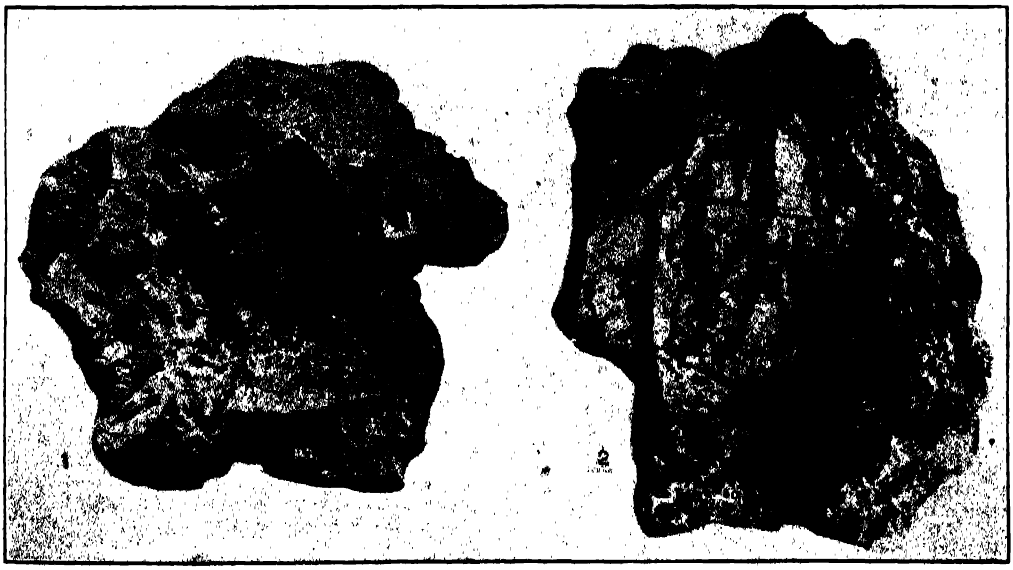


FIG. 2. TWO PIECES OF TRAVERTINE

FOUND AT CHOU KOU TIEN BY DR. BIRGER BOHLIN IN 1928, ONE (1) CONTAINING THE CHIN REGION OF A CHILD'S JAW IN ASSOCIATION WITH FRAGMENTS OF A CHILD'S BRAIN CASE, AND THE OTHER (2) CONTAINING THE FISSURED FRAGMENTS OF AN ADULT PARIETAL BONE.

tocene fossils he found a piece of quartz, a material not known to occur naturally there, and remarked to his assistants: "This is primitive man." For, so he believed, nothing but human agency could have brought this bit of quartz to the early Pleistocene deposit. He had to wait, however, for five years before the evidence was forthcoming which seemed to justify this surprising anticipation. With funds provided by a Swedish patron (Mr. Ivar Kreuger) Dr. Otto Zdansky of Upsala began excavating at Chou Kou Tien in 1922 and took back to Sweden a large collection of material. After examining (in Professor Wiman's laboratory in Upsala) the fossils he had collected four years previously, Dr. Zdansky reported in 1926 the discovery of two teeth, a molar and a premolar, which he declined to define more precisely than *Homo* sp. This discovery excited wide-spread interest when it was publicly announced at the conjoint meeting of the scientific societies of Peking in honor of the Crown Prince of Sweden on October 22, 1926. When writers in the popular press took the bolder course of referring to the original owner of the teeth as "The Peking Man" Dr. Zdansky issued a warning that his discovery "should be regarded as distinctly interesting but not of epoch-making importance." Professor Davidson Black, however, took a different view of the significance of the teeth. He had been profoundly influenced by the memoir published by the late Professor W. D. Matthew in 1915 ("Climate and Evolution," Annals of the New York Academy of Science, Vol. 24, p. 171, 1915). In

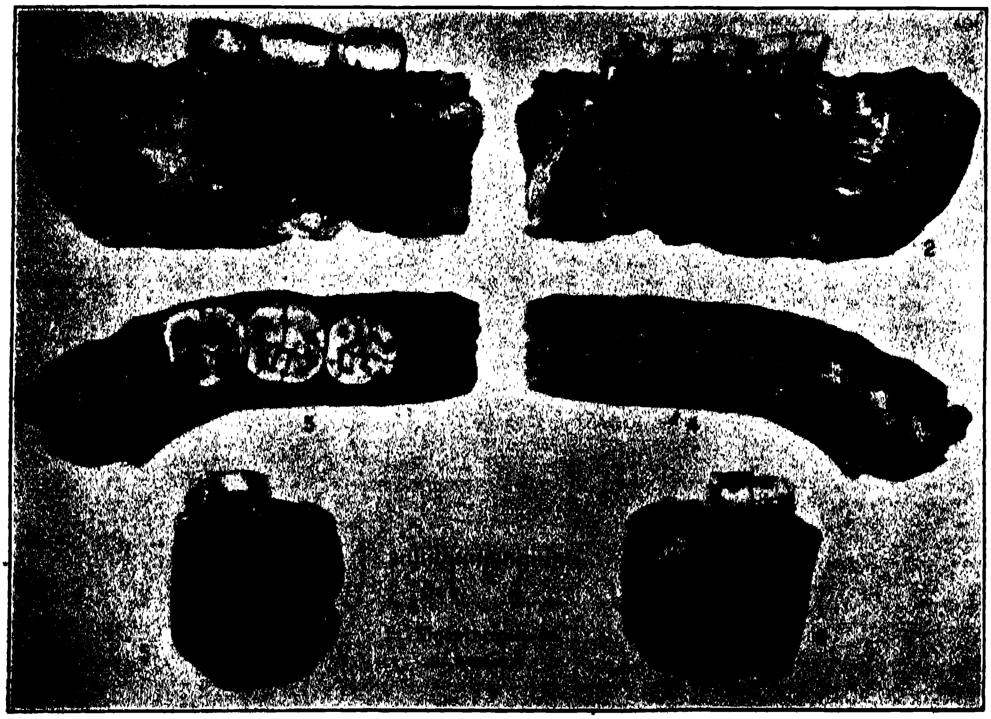


FIG. 3. PART OF AN ADULT MANDIBLE

FOUND ON THE SAME SITE AS THE FRAGMENT (2) SHOWN IN FIG. 2, VIEWED FROM SIX DIFFERENT ASPECTS.

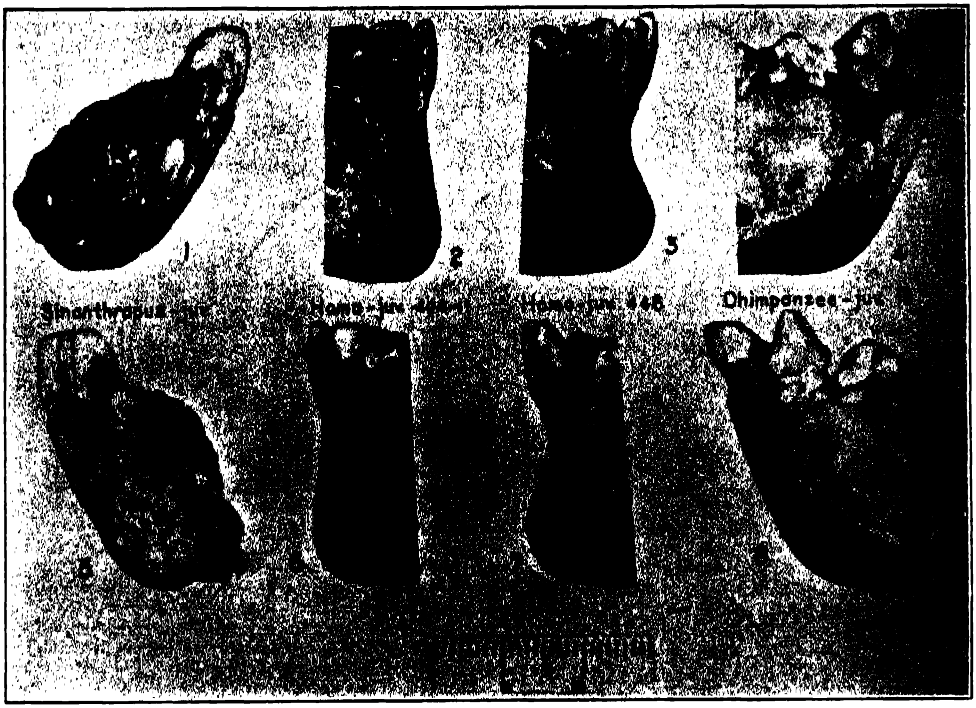


FIG. 4. RIGHT (1) AND LEFT (5) ASPECTS OF THE CHIN REGION OF A *SINANTHROPUS* CHILD

COMPARED WITH SIMILAR VIEWS OF JAWS OF CHILDREN OF CORRESPONDING AGE, NEOLITHIC CHINESE (2 AND 6), MODERN CHINESE (3 AND 7), AND A YOUNG CHIMPANZEE (4 AND 8).

fact, the possibility suggested by Dr. Matthew's argument of the discovery of primitive man in China originally decided Dr. Davidson Black to accept the invitation to join the staff of the anatomy department in the Peking Union Medical College. In 1925 he published a memoir entitled "Asia and the Dispersal of Primates" (Bull. Geol. Soc. China, Vol. IV, No. 2, p. 133, 1925), which revealed the shape his hopes were taking. Hence when Dr. Zdansky a year later found the two human teeth in the early Pleistocene or, as it was then thought, late Pliocene beds, Professor Davidson Black regarded this as a definite realization of the aim which he had set before him several years before, and naturally regarded the discovery as one of momentous importance.

In a communication which, at the request of Dr. Andersson, he made to the scientific meeting held in Peking on October 22, 1926, he emphasized these considerations, and called attention to cogent reasons in support of his belief. The molar tooth found by Dr. Zdansky would seem to resemble in general features the specimen described in 1903 by Professor Max Schlosser. The latter tooth was a left upper third molar having a very much worn crown, extensively fused lateral-roots and from the nature of its fossilization considered by Schlosser to be in all probability Tertiary in age. It was provisionally designated as *Homo* (?) *Anthropoide* (?). It is of more than passing interest to recall that Schlosser pointed out that future investigators might expect to find in China a new fossil anthropoid, Tertiary man or ancient Pleistocene

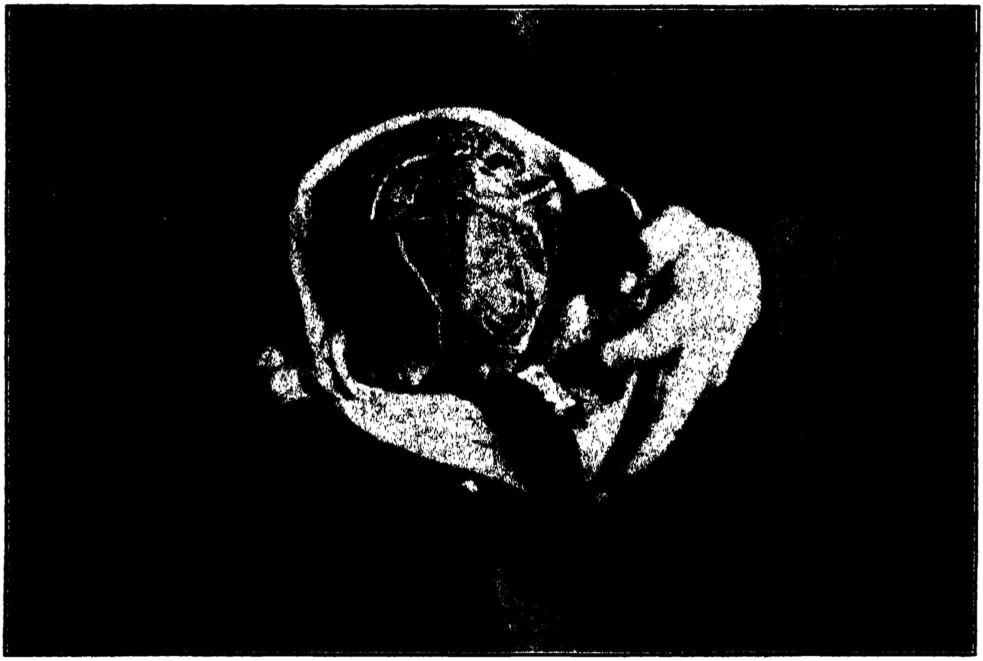


FIG. 5. PHOTOGRAPH OF A CAST OF THE SKULL OF *SINANTHROPUS* EMBEDDED IN THE MATRIX OF TRAVERTINE.

man. The Chou Kou Tien discovery thus affords a striking confirmation of that prediction ("Tertiary Man in Asia," Bulletin of the Geological Survey of China, Vol. 5, 1927, p. 208). To give expression to these convictions, Dr. Davidson Black induced the director of the Peking Union Medical College (Dr. Henry S. Houghton, now dean of the Medical College at Iowa City) and Mr. Edwin Embree, then secretary of the Rockefeller Foundation, to support an appeal to the Rockefeller Foundation for an appropriation to carry on the search at Chou Kou Tien. The late Dr. Richard M. Pearce, at that time director of the medical division of the Rockefeller Foundation, so far appreciated the significance of the possibilities that he induced the Foundation to make an appropriation for two years' work on the site. This project met with immediate success, for on October 16, 1927, Dr. Birger Bohlin found a lower molar human tooth in the deposit at Chou Kou Tien where Dr. Zdansky, in 1922, had found the two teeth reported on October 22, 1926. On December 2, 1927, Dr. Davidson Black announced to the Geological Society of China this important discovery and his courageous decision to use it as evidence for the creation of a new genus and species of the Human Family, which, on the suggestion of Dr. A. W. Grabau, professor of paleontology in the National University of Peking, he called *Sinanthropus pekinensis*. The age of this tooth and the deposits in which all the fossils were found was thought at this time to be Upper Pliocene, but a more careful sifting of the evidence provided by the associated mammals subsequently led the geologists to decide that the real age was Lower Quaternary (very Early Pleistocene). Dr. Davidson Black claimed that the morphology of the tooth left no doubt either of its human origin or of the fact that it was generically distinct from all other known human types. He came to the conclusion that it was derived from a child corresponding in type to that attained by modern children of eight years, and presumed that it was derived from the same jaw as the lower premolar tooth whose discovery was reported in 1926 by Dr. Zdansky. For it seemed improbable that two children of the same age should have left their teeth on this spot.

At the time (1923) when he was preparing his preliminary report on the geology of Chou Kou Tien, Dr. Andersson was impressed by the presence of fossil remains of a true horse and the absence of *Hipparion* and, like Professor Schlosser in 1903, suggested the possibility of the fossil beds, which were definitely earlier than the loess, being of Upper Pliocene age. As a fuller knowledge of the extinct fauna of Eastern Asia was acquired, however, it became abundantly clear (at the close of 1927) that the geological age was Early Pleistocene. The evidence and the arguments have been set out with great lucidity and convincing cogency by Pére Teilhard and Dr. C. C. Young in their "Preliminary Report on the Chou Kou Tien Fossiliferous Deposit"

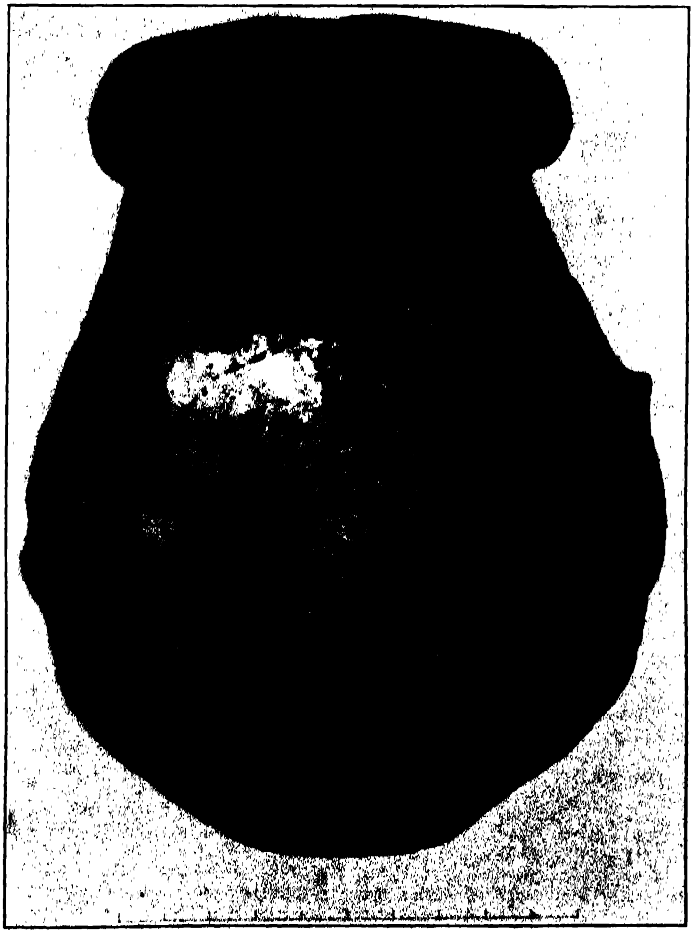


FIG. 6. UPPER ASPECT OF THE PEKING SKULL.

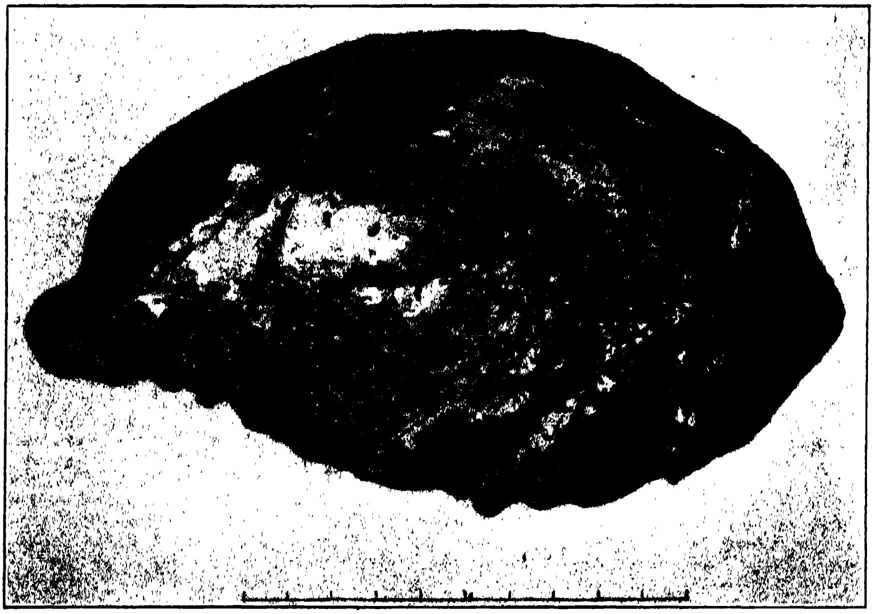


FIG. 7. LEFT SIDE OF THE PEKING SKULL.

(*Bulletin of the Geological Society of China*, Vol. VIII, No. 3, 1929). The absence of truly archaic forms, such as the big *Hipparion*, *Chalicotherium*, et cetera, and the presence of horses and deer with more recent characters proved that the beds were more recent than Pliocene. The absence of fauna characteristic of the Middle Pleistocene loess —*Rhinoceros tichorhinus*, *Bos primigenius*, *Hyaena crocuta*, *Cervus elaphus*, et cetera—and the presence of earlier forms established the proof of its Early Pleistocene age.

The morphological characters of the tooth thus shown to be Early Pleistocene in age suggested that it was more nearly akin to those of the Hominidae than to those of the Simiidae, and the nature of the wear of the tooth afforded important corroboration of this inference. In spite of these considerations, which were set forth with restraint and impressive cogency in an exhaustive monograph ("Palaeontologia Sinica," Series D, Vol. VII, 1927), Dr. Davidson Black's boldness in creating a new genus on the evidence of one tooth gave rise to wide-spread criticism.

A year later, however, in November, 1928, Dr. Birger Bohlin, working in conjunction with Dr. C. C. Young and Mr. W. C. Pei, found additional remains of human skulls which provided justification for the action Dr. Davidson Black had taken in the previous year. In addition to further teeth conforming to the *Sinanthropus* type the material found in 1928 included portions of two lower jaws and fragments of braincases, which probably belonged to the same individuals as the mandibles. The peculiar features of the chin region of these jaws differed from those of all other known human specimens excepting only the Piltdown jaw, to which they presented a general resemblance, without being generically identical. There is a similar ape-like obliquity in the slope of the symphysis and traces of the simian shelf on the lingual aspect of the jaw. Not only do these peculiarities emphasize the peculiar features of *Sinanthropus*, but they also afford welcome confirmation to the views of those who regarded the Piltdown jaw as human. The fact that mandibles with such an ape-like conformation of the chin region were found at Chou Kou Tien in association (Fig. 2) with broken remains of human brain-cases provided valuable evidence in support of the view that the jaws also were human. Hence they contributed weighty support to those who regarded the Piltdown jaw, which had been a matter of controversy for sixteen years, as really a part of the same individual as the brain-case found in association with it.

The importance of the work accomplished during the two years covered by the first appropriation of the Rockefeller Foundation led, in 1929, to the renewal of the grant and the creation of a special department, the Cenozoic Research Laboratory, of the Geological Survey of China, under the honorary directorship of Professor Davidson Black. This significant action was due in large measure to the support of Mr. Roger Greene, the executive head of the Peking Union Medical College.

The confidence which was implied in the granting of the new appropriation was immediately justified by the most impressive and significant discovery in the whole history of human paleontology. At four o'clock on December 2, 1929, Mr. Pei found an uncrushed and almost complete brain-case of *Sinanthropus*. The skull was embedded in a mass of travertine, from which it took Dr. Davidson Black four months to free the skull, a tedious and difficult operation, which required exceptional care and technical skill to accomplish by means of dental drills. There still remained the task of removing the hard mass of travertine which filled the cranial cavity. Dr. Black was anxious not to destroy this natural endocranial cast, and fortunately the skull was that of an adolescent and its sutures were still unclosed. Not only so, but the bones were cracked so that he was able to remove the parietal bones in pieces and examine the texture of the cranial wall.

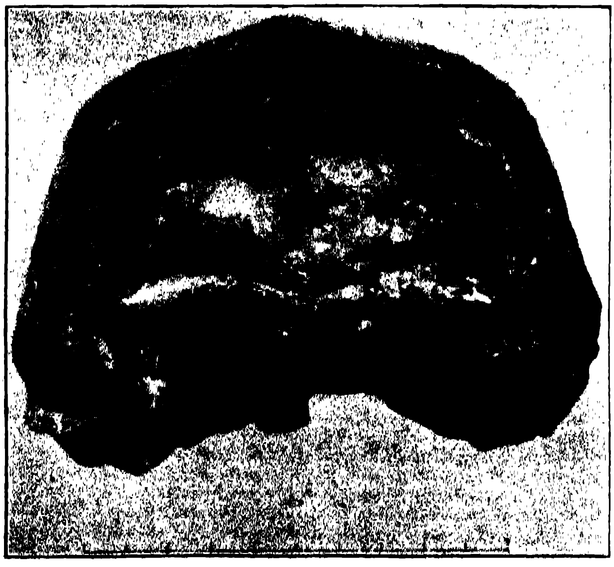


FIG. 8. FRONT OF THE PEKING SKULL.

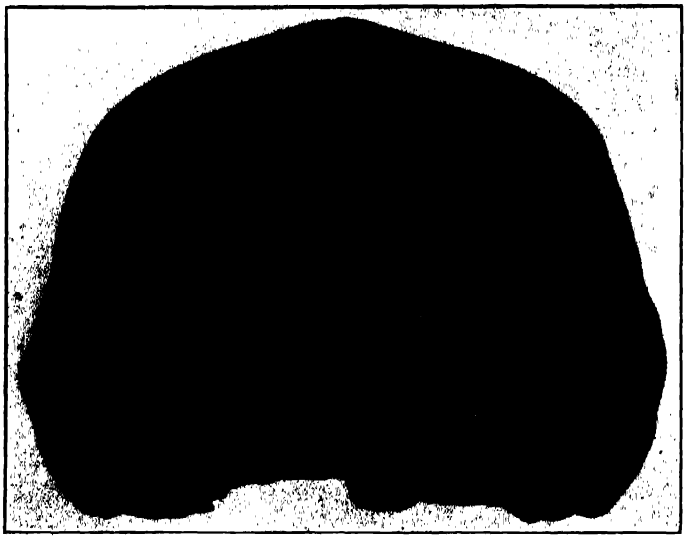


FIG. 9. POSTERIOR ASPECT OF THE PEKING SKULL.

The bones were surprisingly thick and comparable to those of the Piltdown skull both in structure and thickness. It was found possible to remove the frontal, occipital and temporal bones from the surface of the endocranial cast and then reconstitute each of the bones of the skull, so that they could be examined in the way customary among students of the modern disarticulated skull. The bones so successfully disarticulated by Dr. Davidson Black were then fitted together again to reconstitute the skull, from which an artificial endocranial cast has been made.

This important mould of the brain-case can not be further discussed until Dr. Davidson Black has published his official report and photographs of it, It will then provide evidence of profound significance on the problem of how man acquired the distinctive qualities of his brain, which conferred upon him the mental preeminence which made him human.

The fossil is important not merely because it gives a reliable idea of the exact form of the skull of an early Pleistocene man (free from the doubts which arise in the case of a reconstructed specimen), but also because its peculiar features, revealing as they do many points which suggest an affinity with *Pithecanthropus,* associated in the same skull with others such as are known only in the case of the Piltdown skull, form a bond of union between the other two early Pleistocene skulls, the characters of which hitherto have been supposed to be irreconcilable one with the other. In addition to this, the skull of *Sinanthropus* reveals many features which are unknown in either of the other types and throws a great deal of light upon the characters of the common ancestor of the human family, from which all these genera had been derived. One of the most striking illustrations of this fact is the peculiar form of the mastoid region of the temporal bone, recalling as it does the condition found in the newborn child and in the adult anthropoid apes. For it lacks that salient character which is so distinctive of the adult human being in other genera.

The brain-case which was found is that of a young adult corresponding in the state of its development with the condition found in modern human skulls at about sixteen years of age. When the skull was first examined Professor Davidson Black was impressed by the grace of its contours in comparison with the uncouth outlines of *Pithecanthropus,* and suggested the possibility that it might be female, with the reservation, of course, that the evidence at our disposal regarding this hitherto unknown type of being was altogether inadequate for any definite decision upon this matter. Its grace, however, may be due to its primitiveness and the fact that it is free from those secondary distortions which give the degenerate *Pithecanthropus* its bizarre character. The discovery of another brain-case was made in July, 1930, by recovering from material brought in from the Chou Kou Tien cave (in October, 1929) a series of fragments which articulated one with the other to form the greater part of the calvaria. This discovery of a skull of another adult at least ten years older than the one found in December, 1929, revealed a more lightly built skull with smaller eyebrow ridges, a less prominent forehead and less obtrusive parietal eminences, which both Professor Davidson Black and I consider to be probably of different sex to the other skull. It seems not unlikely, however, that the skull reported in July, 1930, may prove to be female and the other skull (found on December 2, 1929) male: but at present neither opinion can be said to be based upon any really decisive evidence. The discovery of a second skull enormously

FIG. 10. UNDER SURFACE OF THE PEKING SKULL.

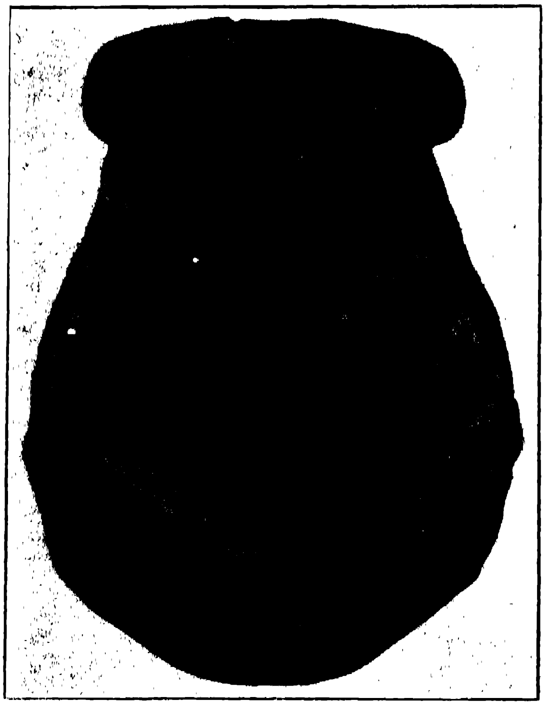


FIG. 11. THE UPPER ASPECT OF THE ADOLESCENT SKULL OF *SINANTHROPUS* × ½ WITH PARTS OF THE PARIETAL BONES AND A SMALL PART OF THE LEFT SIDE OF THE FRONTAL REMOVED TO REVEAL THE NATURAL ENDOCRANIAL CAST. THE GREAT THICKNESS OF THE CRANIAL WALL AND THE CORRESPONDINGLY DIMINUTIVE SIZE OF THE CRANIAL CAVITY IS SHOWN. ON THE RIGHT SIDE (JUST ABOVE THE SQUAMOUS SUTURE) SEVERAL FLAKES OF STONE AND THE TOOTH OF A CAVE BEAR CAN BE SEEN EMBEDDED IN THE ENDOCRANIAL MASS OF TRAVERTINE.

enhances the value of the information we have because it permits comparisons to be made. In the material found in 1928 (Fig. 2) there are remains of two other broken skulls (still embedded in travertine), which provide other important comparative material for studying the range of variation of the skulls. One of the most remarkable points of contrast between the brain-case of *Pithecanthropus* and of *Eoanthropus* is the phenomenal thickness of the latter, whereas the skull of *Pithecanthropus* is much thinner. In the case of the skull of *Sinanthropus* found on December 2, 1929, the thickness of the bone approximates to that of the Piltdown skull. Not only does it resemble it in mere thickness, but the architecture of the cranial vault (which in the case of the Piltdown skull has hitherto been regarded as quite distinctive) is almost exactly reproduced in the case of *Sinanthropus*. In all other known human skulls the cranial bones consist of two fairly thick tables united by a comparatively thin layer of diploic tissue consisting of fine trabeculae. In the case of the thick cranial bones of both the Piltdown and the Peking skulls, the tables are relatively thinner and the thicker layer of diploic bone consists of a very robust network of coarse trabeculae. These similarities suggest that in the thickness and peculiar texture of the cranial bones of two early Pleistocene skulls of different types (separated geographically as their habitats were by the whole extent of the continental land mass between England and China) we are dealing with characters of primitive man for which no close analogy can be found in the apes. This condition in the Piltdown skull was regarded either as pathological or the result of some freakish mutation. But the presence of the same condition in *Sinanthropus* enhances its importance. Why the skull of primitive man should attain such an enormous thickness is difficult to explain: but the evidence provides an interesting problem for morphologists to endeavor to solve.

Did primitive man's skull increase in thickness because the increase in the capacity of the brain-case deprived an increasing area of the protection of the temporal muscles? Or was it because this exposed area of skull was liable to new kinds of risks when men began to use sticks and stones as weapons? These tentative suggestions are much too speculative to be seriously discussed.

Yet there must be some definite explanation of the increased thickness of the skull of primitive man when his expanding brain seems to need more ample protection than the ape enjoys—a thicker cranium with an ampler supply of bone marrow, which his descendants seem to have found unnecessary. For the moment, however, when there is no clear indication as to the meaning of this peculiar morphological feature, it is of interest as emphatic evidence of the affinity between *Eoanthropus* and *Sinanthropus* and of the enhanced importance of the structural peculiarity itself. The contrast in thickness between the cranial vault in *Pithecanthropus* and *Eoanthropus* acquires a new interest in view of the fact that the three (adult) skulls of *Sinanthropus* (one of the fragments found in 1928 is thin because it is part of a child's skull) reveal a considerable range that is sufficient to bridge the gap which separates Piltdown Man from the Ape Man of Java. These interesting morphological features are merely one illustration of a series of interesting facts revealed by the discovery at Chou Kou Tien.

I have already referred to the fact that the discovery of the two jaws in 1928, presenting as they did features hitherto known only in Piltdown Man, raised the possibility that there had been discovered in China a type of human being more closely akin to the Pleistocene man of England than that of the Ape Man of Java, who was geographically much nearer to the Peking Man. When, however, in 1929, the skull was found (and the base was still embedded in the solid mass of travertine) the striking resemblances of the brain-case to that of *Pithecanthropus*

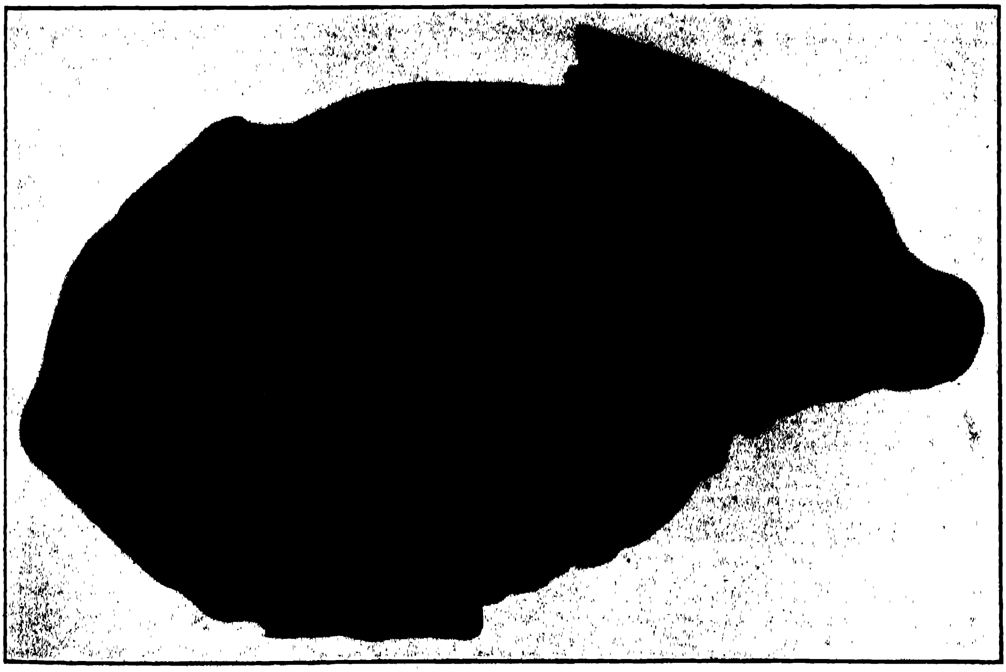


FIG. 12. RIGHT SIDE OF THE SAME SPECIMEN × APPROX. ⅘

DISPLAYING IN AN EVEN MORE STRIKING MANNER THE EXCEPTIONAL THICKNESS OF THE FRONTAL AND PARIETAL BONES.

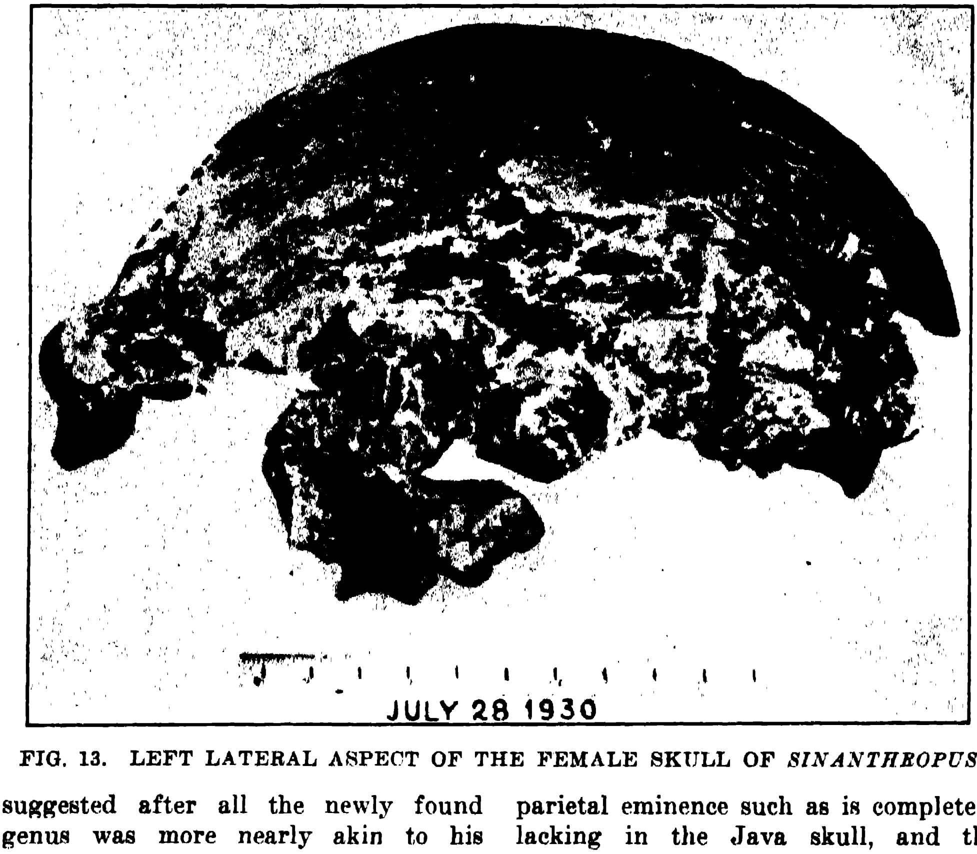


FIG. 13. LEFT LATERAL ASPECT OF THE FEMALE SKULL OF *SINANTHROPUS*.

suggested after all the newly found genus was more nearly akin to his neighbor from Java. The skull revealed great projecting eyebrow ridges like those of *Pithecanthropus*, which provided a marked contrast to the condition found in Piltdown Man in which such ridges were lacking. The front part of the skull was also flattened and ill-filled, and had a prominent median crest such as that of *Pithecanthropus*. There was the difference in the frontal region of the bone, however, that the frontal eminences were definitely more obtrusive than those of *Pithecanthropus*. Turning to the consideration of the parietal bones one finds a close resemblance to those of the Piltdown Man. This resemblance depends both upon the fact that the bones tended to be raised up towards the middle line and are not so flat as those of *Pithecanthropus*, that there is a very definite parietal eminence such as is completely lacking in the Java skull, and the postero-inferior corners of the parietal bones are everted in that peculiarly distinctive way found in the Piltdown skull. The occipital bone again presents a much closer resemblance to that of *Pithecanthropus*, and when we turn to consider the temporal bones we find a much more primitive condition of the mastoid and of the tympanic bones than that which is revealed in *Eoanthropus*. Unfortunately the temporal bone of *Pithecanthropus* had not yet been discovered, so that we can not institute comparisons between *Sinanthropus* and *Pithecanthropus* in this respect. One of the most interesting features of the specimen found in 1929, a feature which Dr. Davidson Black inferred from the nature of the wear of the teeth long before the skull was found, is the fact that the condyloid fossa for articulation with the mandible presents a very close resemblance to the condition found in modern man, both in size, depth and direction. This fact is all the more remarkable because in other extinct members of the human family, in particular Rhodesian Man and Neanderthal Man, there are much more profound differences in the under surface of the temporal bone. The preservation of the condition which became a permanent factor in *Homo sapiens* suggests that the *Sinanthropus* is a primitive generalized type and that modern man has retained many of these primitive characters. Looking at the skull as a whole, one can say that its general form is intermediate between the conditions found in *Pithecanthropus* and *Eoanthropus*. It enables us to unite into a solid foundation the characters of the three most primitive members of the human family at present known. In giving coherence to this knowledge it also enables us to picture the nature of the common ancestor of all three, the as yet hypothetical Pliocene Man.

The suggestion has been made that the Peking Man's distinctive features are not sufficiently pronounced to exclude him from the genus *Pithecanthropus*. When the skull was still embedded in the mass of travertine, its similarity to the calvaria of *Pithecanthropus* impressed most of those who saw the photographs of it (Fig. 5). But, as Dr. Davidson Black pointed out in 1929, the fulness of the frontal and parietal eminences afforded definite evidence of its generic distinction. Since it has been extracted from the matrix, the contrast between the skulls (and in particular the endocranial casts) is revealed in a more emphatic way. Hence it is unfortunate that several paleontologists (for example, Dr. Hans Weinert, "Menschen der Vorzeit," Stuttgart, 1930, p. 39), in Germany and elsewhere are expressing the opinion that the Peking Man should be included in the genus *Pithecanthropus*.

The whole configuration of the skull, the texture of the cranial bones, the morphology of the frontal, parietal and occipital bones, as well as the distinctive features of the teeth and mandible clearly differentiate Peking Man from the Ape Man of Java and present a contrast which is so profound as to compel us to accord it generic distinction. In many respects it differs from *Pithecanthropus* and resembles *Eoanthropus*, but the contrast to the latter is even more obtrusive. It occupies an intermediate position between the two, but is more primitive and generalized than either.

Further discoveries of remains of *Sinanthropus* are still being made at Chou Kou Tien, and during the next couple of years we can only hope that the flair which the young Chinese geologist, Mr. W. C. Pei, has shown in his epoch-making discoveries, in 1929 and 1930, will lead to the finding of still more important remains of the most primitive and illuminating type of archaic men so far revealed.

Whether or not the Peking Man was older than the fossils found in Java and Sussex, there was no doubt that he represented a more primitive type. His characters were more generalized, some of them distinctly reminiscent of man's simian ancestry and others strangely foreshadowing the qualities hitherto regarded as distinctive of *Homo sapiens*. In other words, *Sinanthropus* enabled us to picture the qualities of the original members of the human family by revealing a type which, though human, was curiously ape-like, and obviously close to the main line of descent of modern man.

The work of investigation and of recording the results of the work has been carried on with exceptional thoroughness and imaginative insight. It was hoped by Dr. Davidson Black that the prompt publication of bulletins and the wide circulation of the manuscript reports even before they were published, would have prevented the development of such misunderstandings as had marred the discussions of the fossil remains of man in the past. In spite of these precautions, eminent paleontologists in Germany and France are already claiming that the Peking Man belonged to the genus *Pithecanthropus;* others in America have suggested that he was only a Far Eastern example of Neanderthal Man; and others again that the Chinese fossils were not human.

Having just made a careful examination of the actual fossils in Peking and compared them with human and simian skulls and the casts of the other kinds of extinct members of the human family, I can confidently support the opinion of Dr. Davidson Black that *Sinanthropus* was an undoubted member of the human family who revealed in every quality of his skull evidence to distinguish him from all other known human types, and to justify the separate generic rank suggested to define his status.

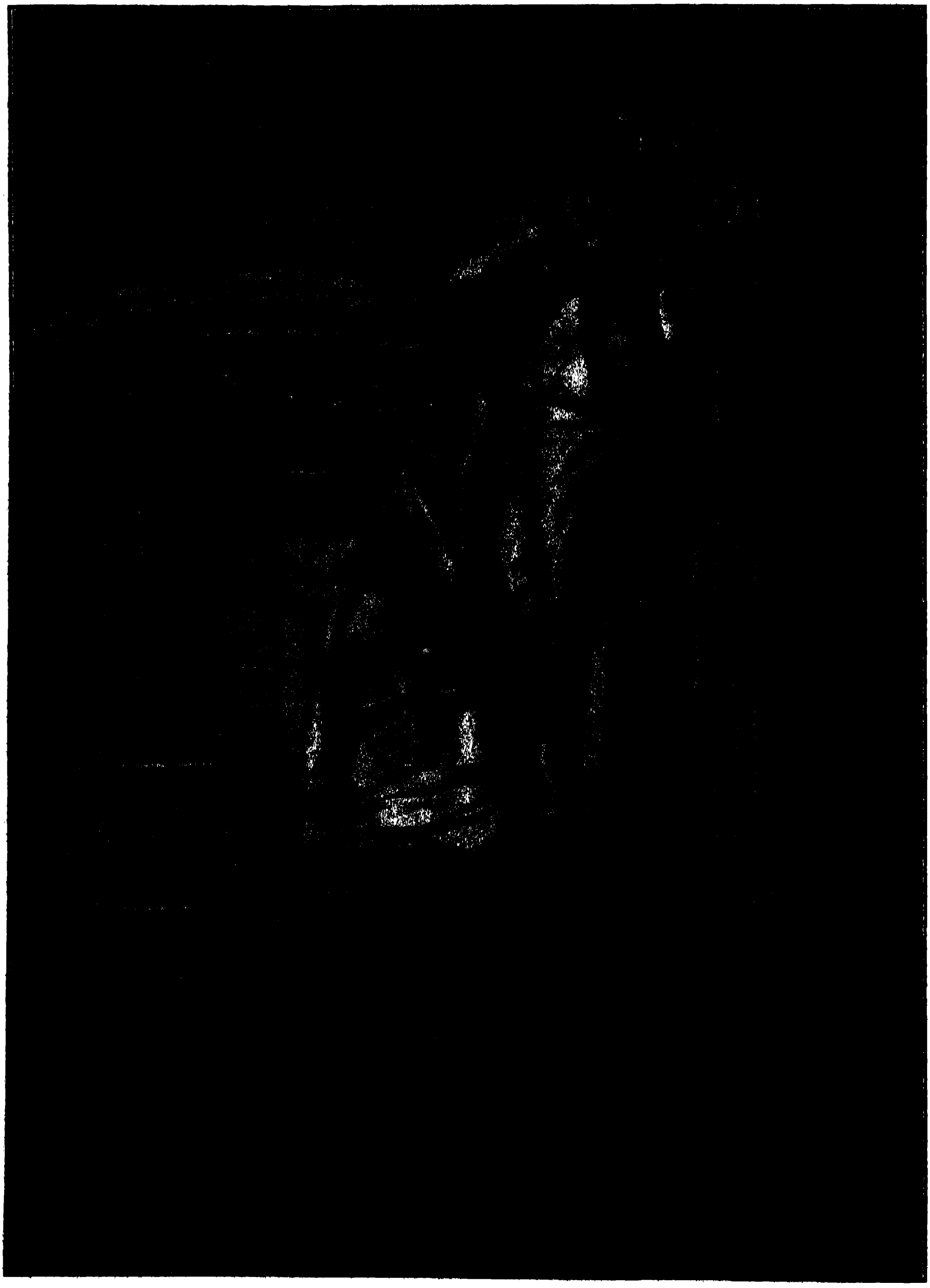
THE CRADLE OF THE HUMAN FAMILY

It has been assumed by certain writers that the discovery of this skull in eastern Asia and the earlier finding of *Pithecanthropus* in Java afford definite grounds for locating the original home of the human family in Asia. I should like to take this opportunity of pointing out that the evidence affords no warrant for such an interpretation. Long ages before the human family came into existence the anthropoid apes had wandered up and down the vast continental mass ranging from western Europe to eastern Asia and to the heart of Africa. The distribution of the Miocene and Pliocene fossil remains of *Dryopithecus* and of *Pliopithecus* and the discovery in South Africa of the ape Professor Dart has called *Australopithecus* (to which Dr. Robert Broom now assigns an age of the early Pliocene) revealed the fact that the anthropoid apes, more profoundly hampered in their range of movements than are human beings, and less able to adapt themselves to different environments, were able to roam from one end of the area occupied by primitive man to the other, probably millions of years before man himself appeared upon the scene. Hence the finding of fossil remains of early Pleistocene man in England, China and Java does not necessarily throw any light upon the home of the much earlier (Pliocene) common ancestor of these three genera, seeing that ample time was allowed for the much nimbler and more rapidly migrating human members of the Order to roam from one end of the territory to another. Seeing that the common ancestors of the anthropoid apes and men probably occupied northern India during the Miocene Period, and that the members of that family displaying the closest affinity to man, namely, the African anthropoids, the gorilla and chimpanzee, *Dryopithecus* and *Australopithecus*, all wandered to the west, I am inclined to accept the view expressed in 1871 by Charles Darwin that, while evidence is not yet available to answer the question, Africa seems to be a more likely home for the human family. Professor A. W. Grabau has revived ("Asia and the Evolution of Man," *The China Journal*, Vol. XII, 1930) the old suggestion, based upon the climatic changes induced in Asia by the upraising of the Himalayas at the close of the Oligocene, in favor of the likelihood that man's Miocene ancestors may have found in the Tarim Valley (or elsewhere in Chinese Turkestan) ideal conditions to stimulate their progressive evolution. I fully recognize the cogency of his arguments and the brilliant persuasiveness of his exposition, and am quite ready to be converted to his views if and when positive evidence in corroboration of them is forthcoming.

The series of fossil remains of man which are now available provide very significant evidence in the casts of their cranial cavity of the changes which were occurring in the brain to confer upon *Homo sapiens* the skill upon which the attainment of wisdom so largely depends. For although no one would assume that we have yet found a linear series of ancestors, at the same time by comparing the form of the endocranial cavity in the various extinct members of the series we can detect a progressive expansion of the brain in an orderly fashion which is of particular interest because it agrees with the order in which the cortical areas in the brain of the growing child reach their maturity and their full functional significance. We are gradually acquiring from the study of the endocranial casts of fossil men in comparison with those of the anthropoid apes and human children some light upon the essential differences between the brains of apes and men. It now becomes a matter of special interest to interpret the processes which went on in the brain to confer upon man his supreme distinction—the human intellect.

THE ABSENCE OF ARTEFACTS

In studying the remains of early man it is always a matter of particular importance to search for the tools and implements which might bring the human beings into association with some definite phase of industry. It is a very significant phenomenon that at Chou Kou Tien, in spite of the most careful search in the caves during the last three years, no trace whatever of implements of any sort has been found. When it is considered how vast a quantity of fossil remains has been found and the scrupulous care which has been exercised in the search, it must be something more than a coincidence that no trace of any stone implements has been found. Not only have the various excavators been on the constant lookout for such artefacts (in particular, Father Teilhard de Chardin has been looking for archeological evidence), but after the material was removed from the caves, a group of boys was set to sift the material once more to make quite certain that no such evidence had been overlooked by the geological explorers. It must not be forgotten, however, that Dr. Andersson, in 1921, found pieces of quartz in association with the fossil bones, and that in the later stages of the excavation Mr. Pei found further examples of this alien material. Those who have been searching in vain for evidence of human craftsmanship on this site are being forced to the conclusion that the Peking Man was in such an early phase of development as not yet to have begun to shape implements of stone for the ordinary needs of his daily life. Whether or not he made tools of wood or other perishable material it is impossible to say, but presumably the chances are that a creature who had acquired the type of brain which is distinctive of the human family, the development of which is intimately associated with the growing skill and understanding, would have used implements of some sort, if nothing more than sticks, to protect himself and to obtain food either by digging or by killing animals.



—*Photograph from the New York State Museum*

THE JOSEPH HENRY MONUMENT

RECENTLY UNVEILED IN ALBANY. IN THE BACKGROUND IS THE ALBANY ACADEMY WHERE JOSEPH HENRY MADE HIS IMPORTANT DISCOVERIES IN ELECTROMAGNETISM.

JOSEPH HENRY

By EDITH W. STONE
PHILMONT, NEW YORK

JOSEPH HENRY, American physicist, was born in Albany, New York, on December 17, 1797. Many books give the date of birth as 1799, but it is the former date which appears in the official baptismal records of the First Presbyterian Church of Albany, founded in 1763. Henry was of Scotch descent, his ancestors, both maternal and paternal, having come over from Scotland on the same boat just prior to the battle of Bunker Hill. Little is known in regard to this father, William Henry, though we do discover that he was a day laborer and that he died when the lad was about ten. , Many years later Henry wrote in a letter to Professor A. M. Mayer, one of his associates: "I have been sorry that my grandfather, in coming from Scotland to this country, substituted it (the name Henry) for Hendrie, a much less common, and therefore more distinctive name."[1] This would seem to indicate that the inability to trace the early history of the Henry family was due in part to the change in name. Henry's mother, Ann Alexander, is described as a woman of marked refinement and gentle mien. Caroline, Henry's daughter, thought that the Alexanders originally came from Argyleshire, Scotland, and that the family were descendants of the Earl of Stirling.[2] Beyond these few isolated facts, the writer was unable to trace the genealogy of either the Henry or the Alexander families.

At an early age Joseph left Albany, for what reason is not known, and made his home at Galway with his uncle. This man, John Alexander, was a twin brother of Henry's mother. In this small town the boy attended the country school, but he was in no way an unusual scholar, as he applied himself to his work in a more or less desultory way. It was due to the following peculiar experience that a change was effected in his hitherto uneventful life. Among other animals on the farm, Joseph had a pet rabbit which caused him many unhappy moments because of its various expeditions to neighboring fields and gardens. One day, while in pursuit of this exploring animal, Joseph saw it disappear within the cellar wall of the village meeting house and church. The boy at once removed a few more stones from the broken wall and followed the rabbit within, but seeing a book that had fallen through the timbers to the cellar floor, he immediately forgot the errand that had brought him there. The book happened to be Brook's "Fool of Quality," and was but one of several books which the boy presently discovered in a case in the small library on the floor above. From the perusal of this book of fiction dated Joseph's love for reading. At that time, when school hours were over, the boy acted as clerk and general helper in the village store, but during his free hours he made frequent use of his secret entrance to the library. Here he read books of romance and thrilled over the experiences described therein. His employer, as soon as he learned of the boy's awakened interest in reading, procured him entrance through legal channels, with the result that Joseph brought his books to the store in order that both he and his employer might spend many hours reading and talking over the contents of the various volumes.

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[1] Published by Order of Congress: "A Memorial of Joseph Henry," 1880, p. 507.

[2] Wm. Henry Eldridge, "Henry Genealogy," with appendix containing brief accounts of other Henry families, 1915, p. 128.

Life went on in this manner until Joseph was about fifteen, when he returned to Albany to live with his mother. Here he was apprenticed to a watchmaker until this man failed in business. His next venture, generated no doubt by his reading of fiction, was in connection with play producing. For the better part of a year he turned his attention to the stage; he worked out stage setting effects, and he even wrote a play in which he took one of the parts. He was not destined, however, to become an actor, as his next endeavors, set in motion by reading while he was ill a book on natural history (Dr. Gregory's "Lectures on Experimental Philosophy, Astronomy, and Chemistry") took him into the scientific world. He now realized that his capacities and inclinations pointed to a field of work far removed from the stage, and to better fit himself for a higher position in life he began to attend night classes. Later he entered Albany Academy, where he paid his expenses by teaching in country schools and by tutoring in the city. After his course of work at the academy was finished he tutored for a time in the Van Rensselaer family. He nevertheless kept up his studies in chemistry, anatomy and physiology, as it was his intention to study medicine at a later date. But in 1825 he was sent out to make a survey for a state road, and in his new enthusiasm for this pursuit he decided at once to make engineering his life work. The next year, however, he was offered the position of professor of mathematics at Albany Academy, an appointment which he accepted immediately. Although his work here required many hours of exacting duties, he still found time to do research work, and it was here he began the experiments that resulted in the development and perfection of the electromagnet. One principle worked out by Henry and established during his professorship at the academy was that of the electromagnetic motor. His next work was in connection with the electric telegraph, for by bringing into use his electromagnet, he made possible the transmission of power at a distance. Just before he terminated his connection with the academy, he discovered electromagnetic induction.

Four years after he accepted the professorship at Albany Academy, in 1830, he married his cousin, Harriet L. Alexander, of Schenectady. Six children resulted from this union, three of whom were living at the time of Henry's death. Mrs. Henry died in 1882, four years after the death of her husband.

In 1832, Henry was offered the chair of natural philosophy at the College of New Jersey (now Princeton), a position that he occupied for fourteen years. During this time he became much interested in the problem of education, which he thought should include "training for both the observing and reasoning faculties";[3] the method of training he emphasized was that of "philosophical investigation." It was during these years at the College of New Jersey that Henry investigated thoroughly the higher orders of induction, which led to his independent discovery of the phenomena of wireless telegraphy.

To go back a few years, I should like to mention James Smithson, an English chemist, whose death occurred in 1829. According to the terms of his will, he bequeathed funds "To Found at Washington, D. C., an Establishment for the Increase and Diffusion of Knowledge among Men." This institution, not actually established until 1846, became the center of much of Henry's later work, as he was chosen for its first secretary and held this position until his death in 1878. More will be said about this institution later.

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[3] Published by Order of Congress: "A Memorial of Joseph Henry," 1880, p. 62.

Due to Henry's work at the three places of learning with which he was intimately connected, and for the reason that he helped to develop the science of electricity more than any other American, he earned the reputation of being one of the greatest of experimenters. Cuyler Reynolds, in writing of Henry's achievements, says that he perfected more than one thousand actual experiments.[4] At the time of Henry's appointment as secretary of the Smithsonian Institution, Sir David Brewster, a Scottish physicist and president of the British Association for the Advancement of Science, made the following statement, indicative of the high standing of the American: "On the shoulders of young Henry has fallen the mantle of Franklin."[5] During his professorship at Albany Academy, Henry began his first real experimenting that resulted in the development of the electromagnet. We know the electromagnet as a core of soft iron which becomes a magnet temporarily when an electric current is passed through a coil of wire surrounding it. In 1827, when Henry first started his work, an electromagnet of very simple design, invented by Sturgeon, was in use. This was merely a piece of soft iron bent into the shape of a horseshoe and then varnished to furnish insulation, after which a piece of wire was wound about it, as shown in Fig. 1. This instrument did not prove to be much of a magnet, so Henry began working to develop a more powerful electromagnet. He first insulated the conducting wire with silk thread, then he wound it around the iron bar very closely in order to have a greater amount of wire through which the current could pass. Hitherto no one had used covered wire, and the single layer of naked wire used was insulated from the iron core and each turn of wire from the next, by a layer of sealing wax. Fig. 2 illustrates Henry's principle. By further original ideas in the construction of his apparatus, he succeeded in making electromagnets of still greater power and effectiveness. His improvement included a longer insulated wire than had been used before; instead of using only one layer, he wound one over the other, inserting a piece of silk between the layers to make the insulation greater. Instead of a single helix around the bar of iron, he constructed a compound helix, that is, he wound about the bar many coils, leaving the ends free. (See Fig. 3.) These ends were then soldered to allow for the distribution of the current among the coils in such a manner that the effect of different distributions of current could be tested. Much credit is due Henry for the development of this magnet, because it was most helpful to him in his discovery of the methods of winding necessary to perfect the quantity and the intensity magnets.

Electromagnets constructed on this plan are still used, as is also the spool magnet—the principle of which belongs to Henry—whereby the wires are wound on spools that slide up and down on the bar, as shown in Fig. 4. Mr. Wm. B. Taylor said, in speaking of this spool magnet:

> Not until after the publication in January of 1831 of Henry's experiment was it ever employed by *any* European physicist.[6] Henry is also credited with the experiment that demonstrated the difference between the quantity magnet and the intensity magnet, the latter of which he used in constructing the apparatus for his electric telegraph. Some years later his daughter, Mary, in speaking of her father's work, said: "He married the intensity magnet to the intensity battery, the quantity magnet to the quantity battery, discovered the law by

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[4] Cuyler Reynolds, "Albany Chronicles," 1906, p. 682.

[5] George B. Goode, "The Smithsonian Institution 1846–1896," 1897, p. 122.

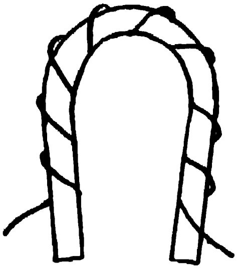

FIG. 1. THE STURGEON MAGNET.

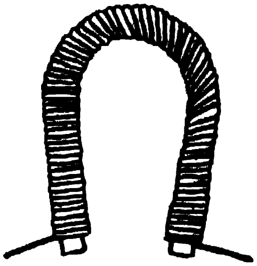

FIG. 2. THE HENRY MAGNET.

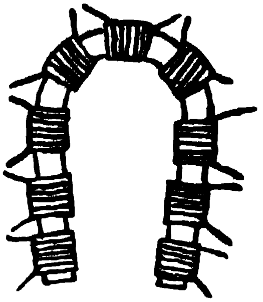

FIG. 3. MAGNET WITH COMPOUND HELICES.

which their union was effected, and rendered their divorce forever impossible.[6]

Henry very early foresaw the possibility of building a machine whereby he could get power from an electric current; and, as there were no dynamos at that time, he had to depend upon primary batteries. After some experimenting, he finally (1829) constructed the first electric motor, and equipped it with the first automatic commutator ever used. His method of construction was as follows: An electromagnet, pivoted at the center, was placed horizontally, with its terminals bent to form contacts, when charged, with two vertical magnets. Around the electromagnet were wound copper wires, the uncovered terminals at either end of the magnet projecting and bending to dip into two mercury cups. Then, as the electromagnet swung and tipped, it made a contact with one battery, while at the same time the other end was free and unconnected. However, the current produced by this contact made the magnet tip in the other direction, breaking the connection with the first battery as it was established with the second.[7] This caused the magnetism in the magnet to reverse, with the result that it again tipped back to its former position. Fig. 5 illustrates the method of construction. Henry, although he said this motion back and forth was produced by ''magnetic attraction and repulsion,''[8] did not consider his experiment to be of much importance. He spoke of his motor as ''a philosophical toy; although in the progress of discovery and invention it is not impossible that the same principle, or some modification of it on a more extended scale, may hereafter be applied to some useful purpose.''[8]

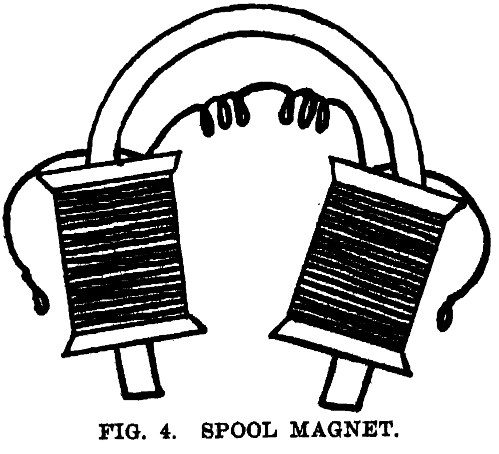

FIG. 4. SPOOL MAGNET.

A third experiment Henry worked upon at the Albany Academy in 1830 was in connection with the electric telegraph. In this experiment he used a permanent magnet, pivoting it at the center in order to allow of free play. Over this was an electromagnet with the permanent magnet so arranged that, in

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[6] George B. Goode, ''The Smithsonian Institution 1846–1896,'' 1897, pp. 124 and 123.

[7] Published by Smithsonian Institution: ''Scientific Writings of Joseph Henry,'' Vol. I, 1886, p. 56.

[8] Published by Smithsonian Institution: ''Scientific Writings of Joseph Henry,'' Vol. I, 1886, p. 54.

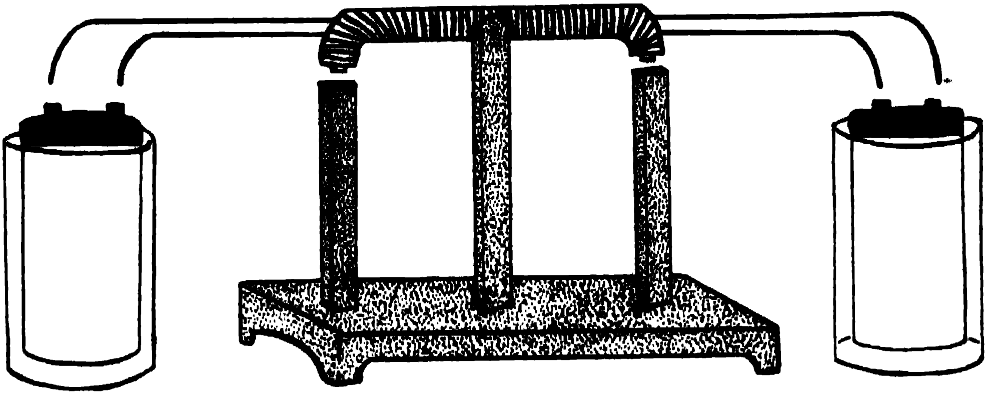

FIG. 5. ELECTROMAGNETIC ENGINE.

pivoting, one of its ends would come to rest midway between the two poles of the electromagnet. The rest of the apparatus consisted of a switch, used in reversing the connections of the electromagnet, and a bell, so located that the permanent magnet, when it moved, would strike against it.[9] In working out this experiment, Henry caused the current to be sent through a mile of fine copper wire. The result was that the little bell actually rang, making an audible signal, and this pointed out the possibility of instantaneous transmission of news between distant points by means of an electromagnetic telegraph. Fig. 6 shows the arrangement of the apparatus used in performing the experiment.

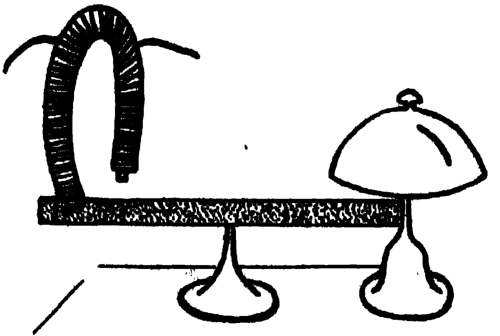

FIG. 6. ELECTROMAGNETIC TELEGRAPH AND BELL SIGNAL.

So to Henry, and not to Morse, belongs the principle and construction of the first electromagnetic telegraph. Morse did, however, develop the possibilities of Henry's principle, for which due credit is given to him. Before he became involved in patent litigation,[10] Morse freely acknowledged his indebtedness to Henry, for he did make use of Henry's intensity magnet, as well as of Henry's device of the telegraph relay, in perfecting his own apparatus. T. C. Mendenhall says:

> While it appears, therefore, that Morse can not justly claim priority in the discovery of a single scientific principle involved in the telegraph, it must be admitted on all hands that he played a most important part in its development.[11]

Another experiment, performed by Henry at the academy in 1831 and said to be his greatest contribution to electricity, led to the discovery of the method of producing induced currents. This is the underlying principle of the dynamo, which as we know it is that in a closed circuit a current may be induced by any change in the lines of force of a neighboring field. Here is Henry's explanation of the principle:

> It appears that a current of electricity is produced, for an instant, in a helix of copper

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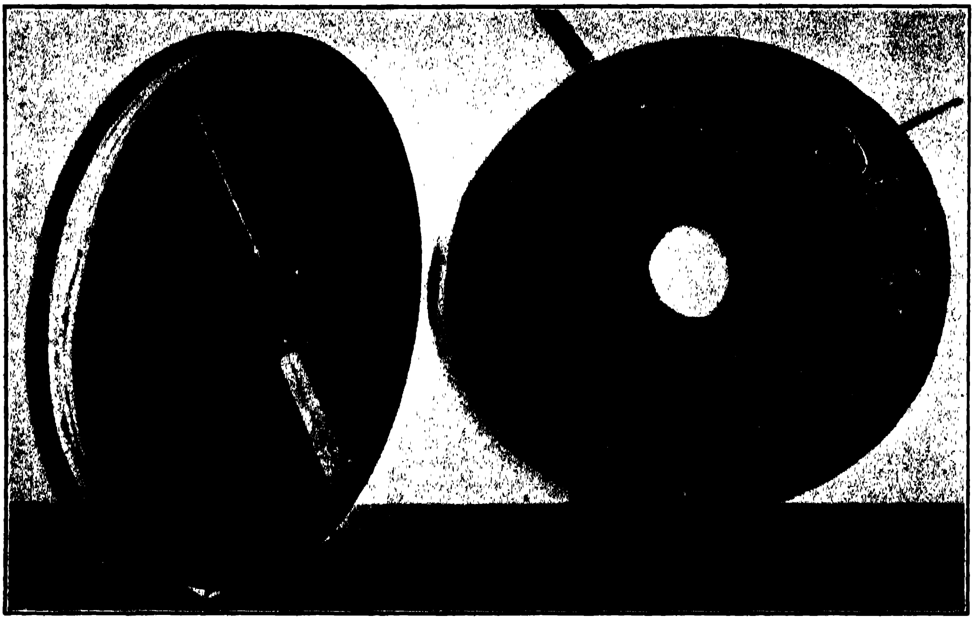
[9] Published by Smithsonian Institution: "Scientific Writings of Joseph Henry," Vol. II, 1886, p. 434.

[10] George B. Goode, "The Smithsonian Institution 1846–1896," 1897, p. 137.

[11] T. C. Mendenhall, "A Century of Electricity," 1892, p. 105.



APPARATUS THAT SHOWS HENRY'S PRINCIPLE OF THE DYNAMO
NOTE HOW CLOSELY THE WIRE IS WOUND ABOUT THE SPOOL.

wire surrounding a piece of soft iron whenever magnetism is induced in the iron; and a current in an opposite direction when the magnetic action ceases; also that an instantaneous current in one or the other direction accompanies every change in the magnetic intensity of the iron.[12]

He described the apparatus as follows:

> A piece of copper wire, about thirty feet long and covered with elastic varnish, was closely coiled around the middle of the soft-iron armature of a galvanic magnet . . . so wound upon itself as to occupy only about one inch of the length of the armature which is seven inches in all. The armature, thus furnished with the wire, was placed in its proper position across the ends of the galvanic magnet, and there fastened so that no motion could take place. The two projecting ends of the helix were dipped into two cups of mercury, and there connected with a distant galvanometer by means of two copper wires, each about forty feet long.[13]

Henry then called an assistant to make and break the circuit, while he watched the needle of the galvanometer, and he was made aware of a current of electricity by the momentary deflection of the needle, first to the west as the circuit was made, then to the east as it was broken. Henry told his assistant in Albany that he had visioned this experiment one night after he had retired and that the next morning, in his small laboratory, he actually drew a spark from the magnet. The writer has seen the original apparatus used by Henry in performing this experiment; also the electric motor and the electric telegraph with the small bell attached, all of which have been preserved by the Albany Academy.

Although the results of Henry's experiment were not given out immediately, it is now generally conceded that he worked independently of Faraday, and there is every reason to believe he anticipated Faraday's work. George B. Goode says it was only through the use of the quantity magnet perfected by Henry in 1830 that Faraday discovered magnetoelectricity.[14] Employing Henry's spool magnet to perfect his principle, Faraday concluded his experiments in 1831 and published his results at once. While Henry's discovery was earlier than that of Faraday's, he did not receive credit for it because he failed to make public his results at the time. Henry, in an outburst to one of his colleagues a little later, said: "I ought to have published earlier, but I had so little time. I desired to get out my results in good form, and how could I know that another on the other side of the Atlantic was busy with the same thing?"[14] Dr. Fleming, an English writer and scientist, is quoted as follows:

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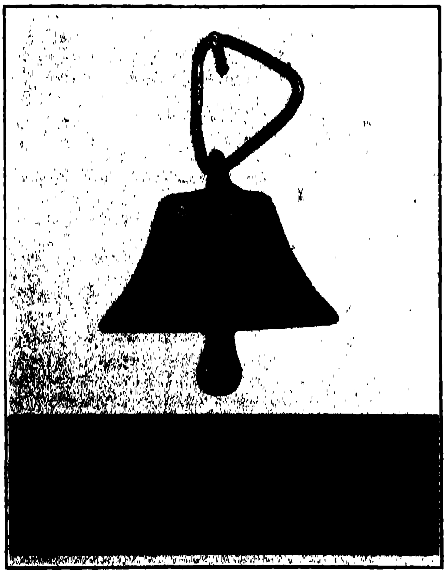
[12] Published by Smithsonian Institution: "Scientific Writings of Joseph Henry," Vol. I, 1886, p. 76.

[13] Published by Smithsonian Institution: "Scientific Writings of Joseph Henry," Vol. I, 1886, p. 75.

> Henry's claim to be an independent discoverer of the fundamental fact of electromagnetic induction is not now disputed. In the July number of Silliman's *American Journal of Sciences*, for 1832, Joseph Henry . . . gave an account of the manner in which he had independently and before receiving an account of Faraday's work performed in the previous autumn, elicited from his own great electromagnet an induced current by wrapping round the soft-iron armature certain coils of insulated wire. In the same paper in which he thus discloses his discovery he rendered an account of that in which he had in turn anticipated his illustrious rival by the discovery of the fact of self-induction of a spiral conductor, and denoted the phenomenon by the name by which it has since been known.[15]

While at the College of New Jersey, Henry added to the principle of the electromagnetic telegraph that of the telegraph relay, thus making telegraphy possible over a considerable distance. Using for the first time the earth as a return conductor, he set up the apparatus between his own home and the laboratory at the college. His device enabled him to open one circuit by means of another, and he successfully demonstrated that it was possible to transmit a current over a considerable distance without any great loss of power. In other words, he showed that it was possible to utilize the power of a quantity magnet through the agency of the intensity magnet. This was Henry's underlying principle of the relay.

During Henry's early years at Princeton, he began a series of experiments which resulted in producing inductive currents of different orders. These currents also had different directions, and were made up of alternate waves in opposite directions. During this series of investigations, he showed that an "induced current may excite a second induced current in a neighboring closed conductor, and this last may induce a third current in another neighboring closed circuit, etc."[16] Henry called



PHOTOGRAPH OF ORIGINAL BELL USED BY HENRY IN WORKING OUT HIS EXPERIMENT OF THE ELECTRIC TELEGRAPH.

THIS BELL IS PRESERVED BY THE ALBANY ACADEMY.

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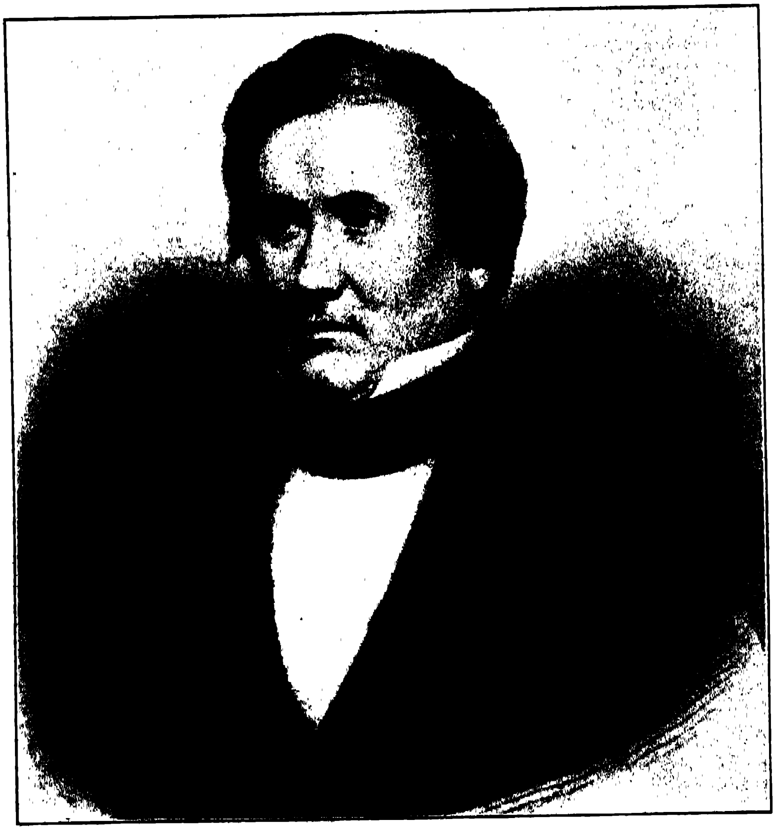
[14] George B. Goode, "The Smithsonian Institution 1846–1896," 1897, pp. 124 and 128.

[15] Bancroft Gherardi, "Joseph Henry's Experiments in the Albany Academy, 1827–1832," 1917, p. 11.

[16] Published by Order of Congress: "A Memorial of Joseph Henry," 1880, p. 494.



I remain very truly
your friend & Servt
Joseph Henry

these currents of the first, second, third, fourth, and fifth orders. He further experimented by placing a piece of metal between the neighboring conductors. Immediately the induction was neutralized, because of the current present in the metal. Later he demonstrated that a current of quantity could produce a current of intensity, and *vice versa.*

Henry's next researches were in connection with ordinary or frictional electricity, by means of which he showed the effects capable of being produced at some distance. He says: "If a shock were sent through a wire on the outside of a building, electrical effects could be exhibited in a parallel wire within the buildings.[17] His investigations covered induction of various kinds, such as atmospheric induction, induction from thunder clouds.

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[17] Published by Order of Congress: "A Memorial of Joseph Henry," 1880, p. 151.

It was at Princeton also, in 1842, that Henry discovered the phenomena of wireless telegraphy, as he noted, in experimenting that the discharge of a Leyden jar through a coil of wire would induce currents in other circuits at some distance away. He noted, too, that these currents did not flow in one direction, but that they oscillated back and forth rapidly. Here is Henry's experiment:

> He passed the electric discharge through a wire round a needle. This object being of highly tempered steel retained the magnetism communicated to it by the current. Henry found that, when the needle was examined after the current had flashed around it, its north and south poles were not always at the ends which should have been produced by the discharge, but were often in the opposite direction, the north pole being the one that should have been south. He immediately saw the cause. The electricity must have flashed first in one direction and then in the opposite one. In perhaps the millionth of a second it not only destroyed the magnetism which had first been produced by the current but induced a magnetism of the opposite kind.[18]

Felix Savary, however, should receive credit for having "first advanced the hypothesis of electrical oscillations as early as 1827."[19] It was left to Helmholtz and Sir William Thomson, afterward Lord Kelvin, to experiment at greater length with regard to these oscillatory currents. Then, in 1887, Hertz proved the existence of these undulations; he measured their length and velocity, which he found to be equal to that of light, and showed that they were susceptible of reflection, refraction, and polarization. Henry, however, should receive credit for his contribution to wireless, because he demonstrated the principle of wireless in his experiment with the Leyden jar. Stated in terms of the present day, Henry showed that whenever an electromagnetic disturbance comes in contact with a conducting circuit, there is set in motion in that circuit an induced electric force which oscillates back and forth very rapidly.

Then, as stated above, Henry received a call to act as secretary of the Smithsonian Institution. According to the will of Smithson, a sum of about $650,000 was available for the founding of this American institution of learning. A short controversy over the acceptance by Congress of such a large sum from a man of English birth was speedily overcome, and the money was brought into this country to be reminted. The object of the institution, as organized in 1846, was to "promote science and the useful arts, and to establish a national museum of history."[20] In the completed building were to be housed "all objects of art and of foreign and curious research, and all objects of natural history."[20] It was left to Henry to draw up a program of organization, and in this he tried to conform to the wishes of Smithson as he interpreted the wording of the will.

Henry interpreted the phrase "to increase knowledge" to mean the discovery of new truths of any sort through research and other aids. To make this possible he proposed: (1) To stimulate men of talent to make original researches, by offering suitable rewards for memoirs containing truths; (2) To appropriate annually a portion of the income for particular researches, under the direction of suitable persons.

For the other phrase in the will, "to diffuse knowledge," he suggested the following aid: (1) To publish a series of periodical reports on the progress of different branches of knowledge; (2) To publish occasionally separate treatises on subjects of general interest.

In such ways Henry planned to use the money that it might benefit the greatest

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[18] David Starr Jordan, "Leading American Men of Science," 1910, p. 128.

[19] Published by Order of Congress: "A Memorial of Joseph Henry," 1880, p. 255.

[20] *Encyclopaedia Britannica,* Vol. XXV, 1911, p. 274.

JOSEPH HENRY IN HIS EARLY THIRTIES.

numbers. It is said that some of the early members of the new institution suggested a society similar to the Royal Society of England, but Henry reasoned that this was not Smithson's intention in willing the money to an American city. Henry, it seems, had learned of a former will, whereby the Royal Society of London had been the beneficiary of the sum later willed to the city of Washington, and he concluded that Smithson had become displeased with this society for some reason and that he desired to have his money used in fields of work in some country other than England. A statement in the New International Encyclopaedia gives as his reason for making a new will that "a sense of wrong in the illegitimacy of his birth alienated him from his native land."[21]

During the thirty-two years that Henry acted as secretary of the institution, he was active along many lines. He became president of the American

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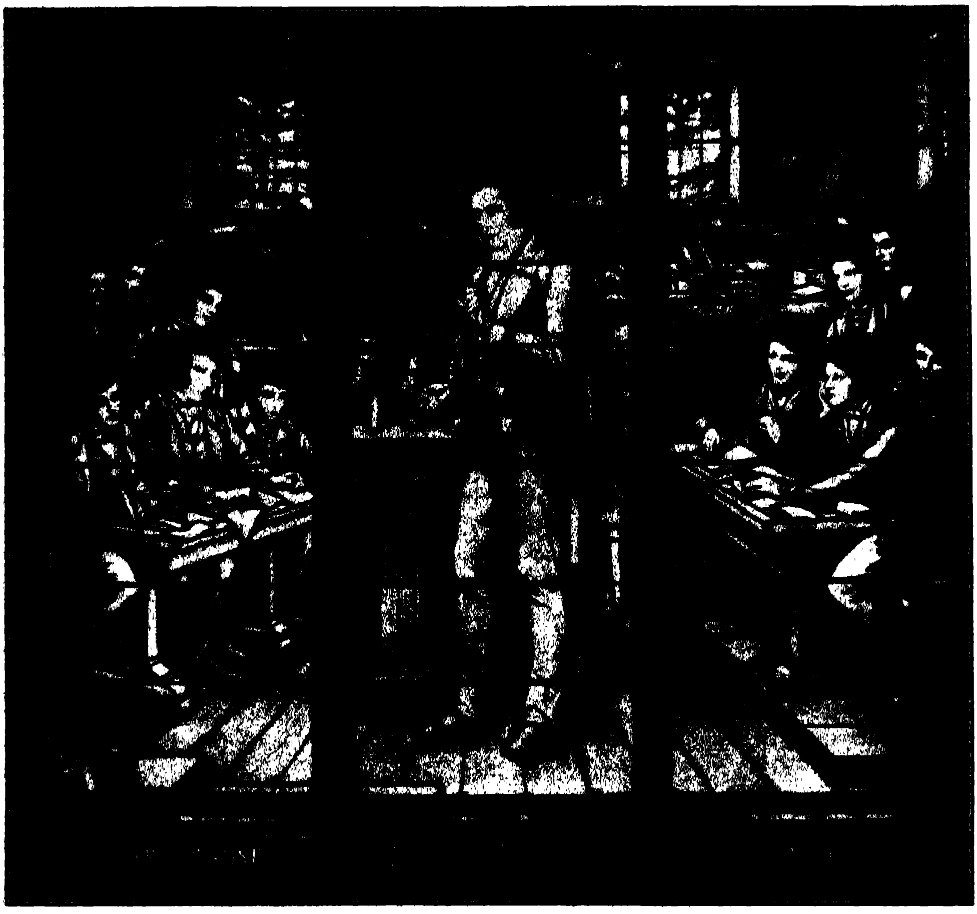
[21] New International Encyclopaedia, Vol. XXI, 1916, p. 205.



JOSEPH HENRY WINDOW IN THE BIBLE SCHOOL ROOM OF THE FIRST PRESBYTERIAN CHURCH OF ALBANY.

HENRY IS DEMONSTRATING, BY MEANS OF A RUDE DYNAMO AND A BELL, THE POWER OF ELECTRIC MAGNETISM. MUCH CREDIT IS DUE MRS. JAMES F. MCELROY THROUGH WHOSE UNTIRING EFFORTS THE FUNDS FOR THIS WINDOW WERE RAISED.

Association for the Advancement of Science in 1849. In 1851, he received the degree of LL.D. from Harvard; he had received this same degree from Union College in 1829. An original member of the National Academy of Sciences, he became its president in 1868. He was also appointed to head the Lighthouse Board in 1871, and in this capacity he helped the government by tests that resulted in improving fog signals and other signal lights used by seamen. As a side issue he was instrumental in getting the government to collect and distribute meteorological information by means of the telegraph. Thus, our present-day weather bureau and weather forecasts are only the development of such service started more than half a century ago by Joseph Henry. Besides, Henry was active in cataloging scientific papers, and in this he sought the cooperation of the British Association for the Advancement of Science. In 1864, when the Royal Society issued its first "Catalogue of Scientific Papers," this tribute to Henry appeared in the preface: "The present understanding may be said to have originated in a communication from Dr. Joseph Henry, Secretary of the Smithsonian Institution."[22]

Some time after he accepted the position at Washington, he was offered the presidency of the College of New Jersey, but he declined this honor because he thought he could reach more people through his work at the institution. He still maintained that his ambition was to add to the sum total of human knowledge by the discovery of new truths which might be of some use to the world; the practical application of these, however, he was willing to leave to others.[22] Like his contemporary, Faraday, Henry did not crave fame; in fact he never asked for but one position during his entire life, and that was during the time he was studying at Albany Academy. In order to earn money to go on with his work there, he sought a position as teacher in a country school district. Because of his immaturity, he was accepted on trial at a salary of $8 a month. He proved so efficient that he was asked to return for the next term at the grand salary of $15 a month. Not only in his youth, but throughout his entire life, the salary given to this man was never in proportion to his services. Mrs. Lucy E. Sanford, in an article published at the time of Henry's death, said:

> He lived on a salary that was a disgrace to the nation and ever an embarrassment to him; . . . large prices had been offered for his name to further private schemes; but he never sold it, and lived within his salary always.[23]

A short comparison of Henry and Faraday,[24] the two men who did so much for the scientific world, seems very appropriate at this point. Henry was born in 1797 and died in 1878; Faraday's dates were 1791 and 1867; each man lived beyond the threescore and ten mark and devoted practically his entire life to scientific work. The parents of both men were working people with only a small amount of education. Henry, as well as Faraday, became interested in the subject of science quite by accident. Henry read his first scientific work while he was forced to inactivity because of illness; Faraday discovered science through reading Mrs. Marcet's "Conversations on Chemistry," during his daily work in a bookbinder's shop. These two men were, to use a present-day term, self-made men; neither had a college education; of the two, Henry perhaps had the advantage, because he did attend the Albany Academy. Faraday attempted self-culture by his attendance at lectures, and as a result he secured the position of assistant in the laboratory of the Royal Institution in 1813. Henry's works and discoveries were many, although only four have been mentioned in detail in this paper—the development of the electromagnet in 1827; the principle of the electromagnetic motor in 1829; the principle of the electromagnetic telegraph in 1830; and the principle of the dynamo in 1831. Faraday's first experiments were in chemistry, but in 1821 he turned to the field of electricity. His first work in that year was in connection with the revolution of a magnetic needle around an electric current. During the next ten years he experimented unsuccessfully in an endeavor to work out the principle of the dynamo, for it was not until 1831 that he discovered the method of producing induced currents. He also discovered the action of one current upon another, and during his later years he devoted his time to researches in electrolysis. Like his contemporary, Henry, he also refused fees and high honors, in order that he might devote himself to the interests of science and his fellowmen. Both these men were gentle and unassuming, but withal deliberate and persistent; and each was filled with a disinterested and lifelong devotion to scientific research.

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[22] George B. Goode, "The Smithsonian Institution 1846–1896," 1897, pp. 132 and 789.

[23] *The New York Observer:* "Professor Henry's Funeral," by Mrs. Lucy E. Sanford, May 16, 1878 (approximate date).

[24] Silvanus P. Thompson, "Michael Faraday: His Life and Works," 1898, pp. 2–299.

Henry had a fascinating personality and, as the magnet with which he worked attracted things to it, so he seemed to draw people to him. Because of his simplicity, his patience, his unselfish nature, his honorable dealings with all, and his many acts of kindness among the poor, he was well received, in this country as well as in Europe. An item published in one of the New York papers shortly after his death described Henry as follows:

> In person, Professor Henry was of more than medium height, and of large and sinewy frame. The kindness of his nature was stamped upon his features and his lips ever bore a patient smile which, however, did not detract from a certain firmness of expression. His manner was gentle, suave and dignified . . . and to his friends, especially to the younger men of science, Professor Henry was always ready to give encouragement in their pursuits and to aid their efforts in opening new pathways of research.[25]

Henry believed in teaching, not by theory, but by practice and by thinking out problems. One might almost call him a true visionary, always active, always looking ahead to some new experiment, never able to decide things hurriedly, yet always persisting until he had reached some definite conclusion. Even as a youth he was very deliberate. A story that shows this habit of deliberation is told about the first pair of boots he ordered from the village bootmaker at Galway. The young man, faced with the problem of choosing between round or square toes, saw the boots slowly nearing completion without being able to come to any definite conclusion regarding the style he preferred. Imagine his surprise when one morning the bootmaker presented the finished boots to him, one modeled with a round toe, while the other stood forth in all splendor with a square toe. It is said that from this time forth Henry was more hasty in making decisions about important and weighty matters.

In religion Henry believed in theism, nor was this belief weakened by his knowledge of science. He was a scientist first and always, but he was also a Christian, a member of the Presbyterian Church and a believer in Christ the Saviour. He said that "next to the belief in his own existence was his belief in the existence of other minds like his own, and from these fixed, indisputable points, he reasoned, by analogy, to the conclusion that there was an Almighty Mind pervading the universe."[26] He was much troubled over the conflict between science and religion, but he stated that at times these two would be unintelligible, the one to the other. He said, however, that if each followed the principles of truth, there could be no conflict whatever. He further asserted: "The person who thinks that there can be any real conflict between science and religion must be very young in science or very ignorant of religion."[27]

In conclusion it can be said that, although Henry worked out principles which he left to others to apply, his name will endure for all time, as the word "henry," the standard unit of inductive resistance, is in common use to-day. Dr. Finley says of Henry:

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[25] *New York Tribune:* From a scrapbook item re Joseph Henry, May 16, 1878 (approximate date).

[26] Published by Order of Congress: "A Memorial of Joseph Henry," 1880, p. 199.

[27] John H. Finley, "Address at Unveiling of Statue to Joseph Henry at Albany, N. Y., 1928," p. 11.

"He was in the van of the precursors of what I have often called the televictorian age—the age of the conquest of the far by telegraph and telephone, by radio and motor."[28] Henry died in May, 1878, at the age of 81. The following article appeared in the *New York Observer* in regard to his funeral:

> One by one, or at most few at a time, came and were seated: the President and Cabinet, the Supreme Court, both Houses of Congress, the Academy of Science with representatives from Yale and Harvard and other Colleges, the Diplomatic Corps, the Alumni of Princeton, the Clergy, officers of Navy and Army, the Philosophical Society of the District, District Courts, the Lighthouse Board of the Treasury, Directors of Corcoran Art Gallery, and the Examiners of Patent Office.[29]

Thus did Henry's own nation honor him and acknowledge his rank among her men of science.

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[28] John H. Finley, "Address at Unveiling of Statue to Joseph Henry at Albany, N. Y., 1928," p. 15.

[29] *The New York Observer:* "Professor Henry's Funeral," by Mrs. Lucy E. Sanford, May, 1878.

THE UNITY OF NATURE AS ILLUSTRATED BY THE GRAND CANYON[1]

By Dr. JOHN C. MERRIAM
CARNEGIE INSTITUTION OF WASHINGTON

In development of science adequate study of the vast accumulation of materials makes necessary a degree of specialization which will give to each student close acquaintance with the facts bearing upon his problem. A true picture of nature can be obtained only if the investigator sees every angle of the physiognomy of each object examined. In this acquaintance there must be assurance comparable to the ability we attain in recognizing instantly our neighbors across the street, or our associates in the office. This must be true, whether we are considering sea-shells from remote areas of the world, or infinitesimal constituents of the blood, or barely attainable elements of the starry heavens. Lacking such knowledge, the judgment of science would be open to criticism as resting upon superficial observation.

But intensive specialization brings serious consequences. The student of butterflies, whose soul is plunged into ecstatic tremors by the flashing wings of a rare species, may be wholly unresponsive to stimulation by flight of the swallowtail kite which throws the ornithologist into a state of great emotional exaltation. To both entomologist and ornithologist, the intellectual joy experienced by the pathologist in distinguishing from each other two types of almost formless bacteria may be almost incomprehensible.

Not only may the characters or criteria vary in different groups of things to such an extent that the problem of one student is not appreciated by those in other fields, but each researcher tends to dig himself into so deep a hole, or to fly so high or so far, that often the greater world, with all the other little worlds in it, seems lost to sight.

The day when the "naturalist" could know the details of all subjects is past, but the necessity of seeing the larger field is not less. Many of the major advances in science come through vision of relationship among regions of research which appear widely separated, and yet are connected in a very real sense. So atomic physics of the laboratory has proved to be one of the most important tools in study of the stars. In another direction there can scarcely be a wider gap in nature than that between astrophysics and problems of biological inheritance. And yet a singularly important question is presented by possibilities of influence from cosmic rays, assumed to arise in interstellar space, upon development and variation of certain elements in the living cell.

Some of the greatest discoveries arise through association of persons engaged in study of widely separated subjects, but each sufficiently broad-minded to consider the relation of his work to that of others. Such advance depends in a measure upon experience or training in fields of breadth adequate to open a vision of the larger picture.

Appreciation of the need for considering each problem of nature in the light of its relation to the larger scheme of things may come from contact with any situation in science or in everyday life.

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[1] Read on occasion of inauguration of President Shantz at University of Arizona, April 24, 1928.

It is, however, possible for us to live long without having this revelation of unity as seen through continuity in operation of natural law in time or space.

Perhaps the earliest expression of this view of unity appeared in the idea of one God in Nature, instead of many warring deities. Certainly there has been no greater stride in human thinking than that which extended to the universe the type of coherence that modern science reflects in the law of gravity, or in the marvelously rigid adherence to rules of movement in light.

But the world of thought is not a level plain. In it there are mountain peaks and valleys, and a sudden view over wide fields sometimes gives a startling vision. So with respect to interrelation of the elements of nature, there are places where the picture reveals with exceptional clearness the idea of continuity in law and interdependence of the features involved.

If one were to take the instant wings of thought and flash through the universe of space and time and movement, it is doubtful whether within the range of these wide spaces there would be found another situation presenting as much of continuity through time and action as is seen in the cinema of earth history at the Grand Canyon. There may be other places on this earth that are comparable. If so, they are few. We have no assurance that close similarity to this particular type of relationship will be discovered elsewhere in the universe. I have chosen to turn attention to this concrete thing which touches both our intellectual and our spiritual life. I look upon it as a treasure house of science—an immeasurable influence upon human thinking and ideals.

In this age of experiment we have established the idea that observation of a process is more important than speculation or calculation. The assumed laws or modes of procedure upon which we base calculation may be inexact. If so, the results will express this inadequacy. Experiment is only experience in a measure under guidance or control.

History, whether relating to man or civilization, or to the earth, or to astronomy, is a record of experience. Time and the relative position of events in it represent one way of describing the occurrences. This expression of experience indicates in some measure the laws which have governed action.

To-day the world stands at attention when the astronomer stops in his task to tell us of the history or evolution of worlds, of planetary systems, or of spiral nebulae. Also, regardless of any preconceived notions, all mankind watches with intense interest whatever comes from investigations on the history of man's long-extended striving to better his position and to deepen his knowledge.

But nowhere in the universe of stars, nor in human experience, nor in any other phase of history, do we visualize in a manner more striking than that at the Grand Canyon the presence of moving events of history, with the reality and order of occurrence so visualized that one sees, as it were, the whole panorama in action.

Astronomical measures of space and time reach to figures that we fail to comprehend. We are staggered by the statement that light moving at its terrific pace would require one hundred to two hundred millions of years for passage from some of the more remote spiral nebulae to the earth. In looking out over space, the universe as we see it in different places actually represents different geological ages perceived at the same moment. At the Grand Canyon a vastly longer series of ages, or of different times, is visualized at the same moment and in the same place. The events in the Grand Canyon story are, moreover, presented in such manner as to express continuity of action extending through them.

Outside the field of geology, I am not aware of any actual measure of events in the universe, even remotely related to observation, which involves more than approximately two hundred million years. The story of the Grand Canyon, as seen in a casual glance, gives us, according to the geologist, a reasonable assurance of considerably more than one thousand million years.

The geologist divides his story of the earth into the astronomical period and the strictly geological. For the first he depends upon the astronomer. There is no observatorial record of this part of the past.

The strictly geological record based upon actual relics which we may examine divides itself into three parts: first, an early or Archeozoic, in which the record is heavily defaced by influences that have almost completely changed the remaining materials. No traces of life are found in this rock system.

A second period, or the Proterozoic, is represented by a vast thickness of layers formed upon the earth's surface by processes much like those in operation to-day. From these rocks, resembling mud, sand and gravel of to-day, we have rare remains of life foreshadowing that of the present.

The third division of time, approximating in length the second, includes most of the great formations we meet generally over the world—tens upon tens of thousands of feet of strata, like deposits of to-day, and containing abundant remains of plants and animals.

In a single glance at the walls of the Grand Canyon these three divisions of time are all clearly represented together.

The Archean or the oldest rocks here shown are the torn and mangled remains from an earth of so long ago that almost have the elements destroyed it. The mass was buried at times beneath so deep a load of sediment that it barely escaped complete alteration of every physical character. It was filled with materials that crept into interstices of its shattered body. It was squeezed into mountains and again lifted high till erosive forces in large part wore it away. What we have left represents time and antiquity as does perhaps nothing else that we may find in the universe.

The twelve thousand feet or more of strata of the second great series, beginning at the bottom as it does with masses of rolled pebbles, including fragments of rocks from the first or earliest division, presents a picture of conditions not materially different from those on gravel bars of the Colorado River near at hand. With all their hundreds of millions of years of antiquity, it was on an earth as of yesterday that these deposits formed.

To the casual observer, this story of time in the canyon walls may appear broken by many gaps. But what might be called interruptions are only changes of scene. Where the rolled pebbles of the second great series rest upon the oldest rocks, they are mute evidences of an uplift during which mountains were formed and washed away—perhaps the greatest single story of the region.

The relation of this seeming eternity of action in the story of the canyon to the physical processes of which it is an expression involves questions which we answer only in part. The natural forces that produced these changes are of two kinds: first, those movements of the outer earth which have lifted the continents and mountains; secondly, the agencies which have moulded the uplifted masses into forms of the land.

Of the first element, the movements of the earth now up, now down, the canyon gives reality, though only partial explanation. But we are not ashamed to say we do not know, at any rate when gravitation, constituting an important phase of the problem, remains itself one of the greatest mysteries of nature.

More easily visualized are the forces which have moulded the land. Often as one watches from the brink of the canyon, a cloud floating by is seen to lower a dark curtain of storm. In its path rain lashes the slopes, streamlets flow in the ravines, and mud-discolored waters begin their journey to the sea. This power that carves and wears the land, spreading the debris as record of its work, involves the wind that shepherds swiftly changing clouds, and all the features of the atmosphere.

No one who sees this picture at the canyon fails to realize that as the cloud which shapes itself and vanishes, so runs the story of the land. The rocks we see are only fragments that remain from great formations of ancient time. They bridge the short span of eternity which lies immediately behind us.

It is not possible to consider the geological story excepting in terms of the physical forces involved. It is also true that the nature of these elements is in considerable measure interpreted by the way in which they have operated geologically. In a sense the two problems become one.

To what extent the sources of physical power concerned lie outside this earth is at the moment a question for discussion. Some hold that if not as a cause, at least as occasion, the effect of radiation from the sun, along with gravitational influences, may have bearing upon movements of the earth's crust. The agencies which lifted the bulk of the great plateau high above the sea may, with participation of gravity, have involved light, heat and electric activity, which also give life to the winds and clouds.

The varied features of the scene are in reality one picture, from clouds to forming of the canyon; from the veil of beauty flung over it by shifting light to the immeasurable power that raised and bent the mountains' mass. Whether it be scientist or only one who comes to glory in the work of nature, the value of every part in it is most highly dignified when seen against the background of an interlocking group of elements, each most fully interpretable when considered in its relation to the others.

The Canyon has long been a superlative spectacle without reference to any direct relation it might have to the origin or becoming of life. To-day we see it not only as a place of great physical wonders, but as presenting, embedded in its story, one of the most thrilling accounts of the adventure of life through the ages. As yet this story is largely unknown, waiting for those who will come to chart these wildernesses of the past.

The record of life begins in the lower strata of the second series, the Proterozoic. It leads on up to the highest level of the walls. Then out across the Painted Desert and into the highlands to the north the story continues in still later strata. The multitudes of animals that favored the sea left their skeletons in myriads. Creatures that came out upon the land marked prints of their fingers in numberless thousands on sands of long ago which now form a part of the canyon walls. Dinosaurs pressed their feet into the soft surface, and the traces remained until we could come and wonder. And so into these millions of years of earth building the story of life is woven.

The intertwining of these threads of coming life with those of earth evolution we do not fully understand. The relation is at the same time the greatest mystery and the greatest challenge of the region.

In the presence of such overwhelming physical features as those of the Canyon the living things of to-day that clothe the gentler slopes, or mantle the floor and the plateau above, may seem to have no greater importance than what we have known abundantly elsewhere. But they are of great significance in the larger story of the place, even if it is viewed mainly as a physical picture. In relation to study of the history of life, they express in striking manner some of the most interesting factors involved in the long record of living things entombed in the walls.

As illustrating the idea of interdependence of elements in nature, the garment of life spread over the canyon is an outstanding feature of this great spectacle.

In order that comment regarding significance of the life of the region to-day may be presented through concrete example, I have chosen to view the situation by way of a single incident. Riding through the forests of the North Rim on a recent journey to the Canyon, I saw a flash of black and white. The ranger said it was a "Kaibab squirrel, an animal peculiar to this area." In the branches of a yellow pine we saw him well—a striking figure with tasseled ears and a plump, dark body contrasted with a long white tail. His closest relative, the Abert squirrel, was said to be at home in the same type of forest on the opposite margin of the canyon. Only the gorge of the Colorado separates the areas in which they pasture. But never does either member of the family cross the gulf.

No one who sees these two closely related but strikingly different creatures, and learns that they live in areas separated only by the canyon, fails to ask how it happens that the boundaries of their range can almost touch without overlapping or mixing of the types. Is it chance that they resemble each other so nearly and are at the same time geographically so close? Did the two species migrate from distant regions to encounter this impassable barrier that prevented their knowing each that the other is there at the nearest point across the way? Or were the squirrels here before the canyon formed, or at least before it developed as a sharply separating chasm?

That two animals, each of all kinds in the world most like the other, should journey to a region where they would be separated by such a barrier is possible, but only as a remote chance. That the ancestors of these squirrels were there before the gorge took its present form, and through this separation were divided into groups that gradually came to differ, appears reasonable under certain conditions. It would seem necessary to assume relatively recent development of the canyon, and also that variation in characters comparable to what is illustrated in these types has actually taken place in the past.

In examining the story of these two species it is important to note that not alone do the "Kaibab" and "Abert" squirrels show this interesting distribution in areas separated by the canyon. Associated with them, and separated geographically in precisely the same way, are types of spruce squirrel, chipmunk, ground squirrel and porcupine, along with others.

Concerning the first assumption, touching barriers to migration, it might seem that the canyon has little significance as a bar to movement of plants and animals. Deep as it is, many lateral extensions of the gorge give entrance to its floor. So far as means of travel are concerned, there is abundant opportunity for animals of all types and sizes to reach the lowest level and climb the opposite bank. The torrential river is a hindrance, but many creatures could find their way over it by swimming. Others would be washed across on rafts of debris in periods of flood.

But when the trained zoologist makes his census of life in the canyon according to location, he discovers that many animals competent to move freely up and down or across do not take advantage of this possibility. A map of the whole fauna and flora shows distribution corresponding largely to altitude and to physical and climatic conditions along the walls. In general, only the species of winged animals such as birds and bats extend across the gorge.

The range of climate along the canyon shows the floor to be approximately twenty degrees warmer than the South Rim. In winter, one leaves snow above to pass down through spring into summer. In summer you leave cool nights at the rim to find a zone of tropics below. Standing on the South Rim and looking into the valley of Bright Angel Creek, at the bottom of the gorge, there is seen a region of mesquite, acacia and cactus with environment of the desert. Looking across to the highest land of the North Rim, you discover an area clothed with beauty of pine, spruce and aspen forests. Each zone of altitude has its peculiar conditions of temperature and of plant and animal life.

How these belts of physical condition developed and how they came to have each its peculiar life complement are questions involved in the inquiry whether the canyon and its climatic conditions always existed as we see them to-day.

Some part of the answer as to history of the gorge appears in the fact that the strata in which the canyon is cut are in considerable part deposits such as form only on the floor of the ocean. The upper layer in the walls is composed largely of remains from sea animals. Included are corals and the teeth of sharks. The present position of this limestone, at 7,000 feet above the sea on the South Rim, ranging to 9,000 on the north side, and several thousand feet lower at the town of Kanab to the north of the Kaibab plateau, indicates an immense change of position through uplift and warping.

While this movement of the strata was taking place, or subsequent to it, the stream cut its way across the mass. The possibility of zones of physical condition developed as the region was being lifted. To-day the rocks of this area fill more than two thirds of the habitable space in the atmosphere between sea-level and the zone of an arctic climate at 10,000 to 12,000 feet elevation. These belts of climate were, so to speak, exposed by the river as it cut its way.

Whether or no the squirrels were there before the canyon was excavated, there was a time when these climatic zones, with their possibilities of varying life, had not been developed. If the squirrels had been present in the region at any level of altitude before the canyon was formed, gradually they would have found themselves separated into two groups in areas divided by barriers unfavorable to intermigration. Or if great climatic changes occurred in the course of cutting the canyon the squirrels have shifted their habitat until they are now divided by a gulf of climatic differences corresponding to the magnitude of the chasm.

The second assumption which seems a requirement, if we are to believe that present distribution and differences of the two types of squirrels are related to physical modification of the region, concerned evidence that animals have in the past changed to the extent of difference between these species. This question we may not answer fully by evidence at the Canyon, but most suggestive data are presented.

In the same landscape which shows us such striking illustration of adjustment in present-day life associations to changing topographic and climatic conditions, we see a tremendous spectacle of life as it was modified through the geological ages. This record of the rocks presents proof of abundant life through a vast period, in which the kinds changed many times, and tended gradually to approach types living to-day. The strata in which these remains of animals and plants are buried give evidence that the physical conditions constituting the environment of life varied markedly through geological time. In a manner keeping pace with these modifications in the physical world, the living things changed also.

So in viewing the story of variation and distribution of the tree squirrels in the North Rim and South Rim areas, one comes always to the idea that the account is most logical when seen as an expression of many interrelated factors. There appear to be included the influence of physical changes which we understand only in part, and of biological laws concerning which our knowledge may be even less clearly adequate.

The more closely one studies the time panorama of the Canyon area, the more numerous are the problems raised regarding history of the relation between life of the region and its environment. Among the factors presented we can not avoid recognizing the connection between development of existing zones of life spread upon the walls and the physical changes that produced the gorge. Whether or no this relation indicates direct influence of these developing physical conditions upon the different life associations by which they are inhabited, they at least illustrate an adapting of groups of living things to physical conditions as they varied. In the same way it is difficult to understand the close relationship of species so clearly held apart by sharp geographic separation, without assuming that topographic and climatic changes are among the important factors concerned.

The present status of scientific knowledge does not afford us evidence of experimental type indicating the manner in which the suggested relation between physical environment, varying through time, and changing biological characters has developed. We are at the moment in a stage at which we know that we can not dispense with an environment, and yet do not know precisely what the influence of surrounding conditions may have been. But certain it is that no one can stand before this scene without being conscious of the fact that life as we see it in the landscape to-day mirrors the past and its changes. The unity of nature so strikingly illustrated by intimate relationship between physical factors in this story is no less clearly expressed through linking of biological features to each other, or to development of the physical world in and through which life has grown.

We have seen a picture of the Canyon as visualized by the scientist. But the deep impression which evidence of unity in operation of the forces involved makes upon the investigator may not be more important than that in the case of students of nature concerned only with what is sometimes called the human point of view.

In some respects it is difficult to distinguish the phases of thinking defined as scientific from those known as esthetic or spiritual: The stimulus which drives a great constructive worker in science may separate itself only slightly from that influence leading the master in art or literature to what he considers his mission.

The scientist takes the impression he has received from nature as the starting point for an adventure in securing and interpreting facts. The ultimate result of his effort depends partly upon fidelity to the work of obtaining a knowledge of reality, and partly upon ideals relative to significance of the facts when brought into relation to others.

The great artist or the writer does not set for himself merely the task of describing form and feature of the thing he sees. He attempts to make clear also their meaning to him as an individual human being. In proportion to the extent to which his painting of reality is inaccurate he fails. But he fails completely if his interpretation does not present a true expression of its influence upon him, or its meaning to human kind as typified in his personal understanding or feelings.

It has been stated that nowhere more clearly than at the Grand Canyon does evidence of interrelation in elements and unity of action impress itself upon scientist or investigator. Through such visualization of nature seen as a whole we come often to realization that, even when enlarged by the lens of knowledge, the picture indicates the presence of something beyond that vision does not fully reach. So, in various other ways, artist and writer have presented the idea that, in looking upon these great examples of unity in nature, what we see may be only the shadowy expression of things greater still, which neither eye nor mind has yet been able to define.

THE PLASTICITY OF METALS[1]

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PLASTICITY is the quality by virtue of which a substance may undergo a permanent change in shape without rupture. In many non-metallic plastic materials the flow is essentially fluid. Plastic clay, for example, consists of particles which are or may be non-plastic surrounded by a liquid. During deformation the solid particles move bodily and the liquid conforms to the new shape. The mechanism of the plastic deformation of metals is, however, quite different. Metals are crystalline and plastic flow is the result of block movement of one portion of a crystal with reference to another, the movement being along crystallographic planes. Although a number of non-metallic crystalline substances possess this characteristic to some extent, the metals are in a class by themselves in this respect.

The high plasticity of most industrial metals is perhaps more responsible than any other quality for their wide-spread use. It is an essential property in the application of many metallic products and a necessary one in all metal-working processes. Furthermore, since hardness is measured by resistance to plastic deformation, and methods or treatments designed to change hardness constitute a large part of the metal art, plasticity assumes a major rôle on the metallurgical stage.

History does not record the discovery of plasticity in metals. The discovery that cold hammering increased hardness, however, can be imagined as an unexpected but welcome surprise. When it was found that the bending of a piece of metal hardened it but straightening it again did not restore the original softness, no doubt there was another surprise. In fact, the whole history of the study has yielded one surprise after another and the end is not yet.

Three of the four usual properties determined in the tensile test pertain to plasticity; the elastic limit which represents the beginning of plastic flow, the per cent. elongation, and per cent. reduction of area. Torsion, shear, compression and beam tests also involve a measure of some form of plastic deformation. In the process of breaking a plastic metal by repeated stresses considerably below the static tensile strength, plastic deformation of all or part of the section most highly stressed not only takes place but it is intimately associated with the path of rupture.

Gradually through the centuries the major facts regarding plasticity have become known as the result of manufacturing, using and testing metals and alloys. Certain treatments were found to affect the working qualities favorably and certain other treatments were found to affect favorably the utility. Prior to the advent of the microscope, much dependability was attached to the appearance of the fracture or "grain." A fine grain was needed for most industrial purposes. Fine-grained metal could be drawn into wire with less breakage and a higher degree of roundness than coarse-grained wire. High temperature favored ease of working but tended to produce a coarse grain. This led to low finishing temperatures. Some metals or alloys were found to be brittle at high temperatures and some more brittle at low temperatures. The practice early developed of trying a number of working temperatures for the purpose of ascertaining the most suitable range. It was learned that hot working could be carried on without hardening or without exhausting plasticity, but that cold working, especially the higher melting point metals, resulted in hardening and substantial exhaustion of plasticity. It was also learned that reheating such cold-worked metal would restore softness and plasticity.

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[1] The substance of this paper was presented before Section M—Engineering, American Association for the Advancement of Science, at Cleveland, Ohio, December 31, 1930.

About fifty years ago there began a new epoch in these studies. The microscope came into use as a powerful tool with which to study structures, and physical measurements were undertaken with sufficient precision to learn something of the minor changes accompanying plastic deformation. It was soon found that hot work did not permanently elongate the existing grains but that cold work did. Severe cold work would even elongate the original equi-axed grains into fibers, and reheating to anneal or soften was accompanied by a recrystallization and formation of new equi-axed grains at a temperature far below the melting point of the metal.

About 1886, Bauschinger showed that a metal cold-deformed in one direction had its elastic limit increased with reference to further extension in the same direction but decreased with reference to a load applied in the opposite direction. This phenomenon is still a subject for study and experimentation. Soon after this, Howe showed that rest and moderate heating intensified the strengthening effects of cold work on iron and mild steel, and Muir, in 1900, described these and additional phenomena, now referred to as "over strain." He showed, among other things, that iron immediately after being plastically deformed at room temperature is practically inelastic no matter in which direction the stress is applied. This phenomenon is now thought to be associated with the presence of nitrogen in the iron or steel.

Prior to 1899, mineralogists had studied the deformation of single crystals of non-metallic substances, like calcite, by "gliding," and Mugge, in 1895, had observed similar movements in bismuth and antimony crystals. It remained, however, for Sir J. A. Ewing and Walter Rosenhain, in the Bakerian lecture before the Royal Society, in May, 1899, to put the slip mechanism in metals on a firm foundation.

During the past thirty years there has been great activity in various parts of the world in the further study of plasticity. During the first twenty years of this period the studies were largely carried out with polycrystalline metals, and the x-ray was for the greater part of the period not available as a tool to assist with the interpretation of results. The studies were characterized by the ingenious use of the microscope and the use of almost every available physical and chemical test. During the last ten years methods for the preparation of single crystals of various metals of sufficient size and proper shape for tensile tests and the use of x-ray crystals analysis have enormously stimulated the further study of the mechanism of plastic deformation. The publications have been so numerous and so extensive that no attempt can be made here to give the references. A fairly complete list will be found for the past twenty years or more in the *Journal of the Institute of Metals*. A recent résumé of the literature on translation gliding in crystals has been prepared by Buerger and was published in the February, 1930, number of the *American Mineralogist.*

Nearly all commercial metals are polycrystalline. Variation in grain size is a most important factor in connection with plasticity. Grain shape and grain orientation are also important factors. It would seem that these variations would have been sufficient to baffle the metal workers of the past, but of necessity they had to cope with the added difficulties resulting from alloying. The scientific studies of plasticity are so involved that I shall confine this discussion largely to single-phase metals.

Between 1900 and 1910 some additional discoveries demonstrating the subtle nature of the laws of plasticity were reported. Hadfield tested steels which were ductile at ordinary temperatures and found them brittle in liquid air. Beilby exhausted the capacity for elongation on tensile test of gold, copper and silver by wire drawing and then found that all the wires so produced had over 10 per cent. elongation when tested in liquid air. Hadfield's and Beilby's results seemed inconsistent with each other, but the facts have been subsequently demonstrated beyond a doubt. It may be mentioned here that fine-grained iron or sorbitic steel retains useful ductility in liquid air, but coarse-grained iron or steel becomes brittle at -190° C. It was in connection with these studies that Beilby proposed the amorphous metal theory. He held that amorphous metal harder than crystalline metal was generated on slip planes as the result of slip movement. This theory in the original form has been found to be quite untenable.

During the same decade, tungsten, which was a notoriously brittle metal, was ductilized at the General Electric Research Laboratory. In its ductile state the original grains had been elongated into fibers, the condition for exhaustion of ductility in ordinary metals. To make the anomaly complete, when a fibrous tungsten wire was heated so as to produce equi-axed grains the room temperature ductility disappeared. Here was a metal which did not obey the rules, and its more thorough study resulted in some new rules.

Toward the end of the next decade (1910–1920) commercial experience had established the fact that fine-grained sheet metal could be deep drawn more satisfactorily than coarse-grained material. Similar observations had been made with reference to wire drawing. The results had even assumed approximately quantitative aspects—the larger the grains the less satisfactory the material. The conclusion was drawn that fine-grained metal was more ductile than coarse-grained. This conclusion was not only borne out in processing, but the per cent. elongation and reduction of area on tensile tests also, in general, led to this belief. Coarse-grained zinc was, for example, quite brittle at room temperature, whereas fine-grained zinc was ductile. By extrapolation it might have been expected that a piece of zinc composed of a single crystal would be very brittle.

Imagine the surprise to find by actual test higher elongations and reductions of area in single crystals of zinc than had ever been obtained with even fine-grained metal. The directional properties of crystals had been known for many years, but these results served to rate their importance in a new light. In certain directions, with reference to the orientation of the crystal axes, the capacity for extension is enormous, but in other directions it is practically zero. It is clear now that fine-grained zinc gives a sort of statistical average capacity for extension in all directions and in all parts of the specimen. This makes possible controlled deformation as to shape and direction, and hence fine-grained metal meets commercial requirements. Consider, on the other hand, a wire of zinc composed of grains so large that each one comprises a substantial portion of the cross-section. When wire drawing is attempted the first grain encountered which is unfavorably oriented for plastic deformation in a direction parallel with the length may cause rupture. Thus coarse-grained structures accentuate directional properties and non-homogeneity and fine-grained structures, for all practical purposes, eliminate directional characteristics of the piece of metal taken as a unit.

The study of the plastic deformation of single crystals of various metals and x-ray crystal analysis have greatly enriched our knowledge during the last fifteen years. Hull pointed out that most of the pure metals crystallize with simple space lattices. Face-centered cubic, body-centered cubic and hexagonal lattices are most common. The face-centered cubic lattice represents the most favorable arrangement of atoms for slip movement and the most favorable families of planes are those of greatest atomic density, namely, the [111] and [100] planes. In the body-centered cubic lattice, the [110] planes should be most favorable for slip. There has been some question as to whether the [110] or the [112] planes in iron, as an example of body-centered cubic lattice, are the planes on which slip actually takes place. Most of the results are consistent with the idea that slip is usually on the [110] planes and at times conjugate [110] planes may cooperate to produce slip which appears to be on [112] planes. This point is, however, too involved to expound in the present discussion. In the hexagonal system the basal plane, that is, the base of the unit hexagon, is usually the one most readily permitting slip.

Not only does slip prefer certain families of planes, but there are also preferred directions of slip along any plane. The planes and directions can be deduced with surprising accuracy by considering the atoms as solid spheres. The preferred directions correspond to the V grooves in a layer of tightly packed spheres.

Now comes another surprise. If the grains of a fine-grained metal are at the outset randomly oriented, continued working in one direction, as by strip rolling, will tend to change the fragments resulting from slip toward the same orientation. This is referred to as "preferred orientation." Different methods of working yield different results as regards preferred orientation. Still another complication arises in some metals which form mechanical twins during the course of plastic deformation. Mathewson has greatly enlightened us on this subject, his main contribution being "Twinning in Metals," published by the American Institute of Mining and Metallurgical Engineers, Institute of Metals Division, 1928. One interesting observation with respect to twinning is that most of the actual deformation takes place by slip movement the same as in metals which form no twins. The twinning is helpful in changing the orientation of the crystals in such a manner as to facilitate slip. Also, twinning has an important influence on the orientation of the grains after recrystallization. Mathewson, in coarse-grained zinc which had been alternately worked and recrystallized, has been able to find, by x-ray analysis, the "generations" of twins corresponding to each cycle.

Inasmuch as most commercial metal-working operations effect considerable elongation in one direction, preferred orientation is common in industrial wrought metals. It is not suggested that preferred orientation impairs the utility, but it seems clear that for some purposes it is not desirable. On the other hand, preferred orientation in drawn tungsten wire seems to be a decided advantage in controlling the orientation of the recrystallized grains in lamp filaments. Iron and steel have enjoyed a sort of fortuitous immunity from either the good or bad effects of preferred orientation, at least with respect to many commercial products, like structural steel and rails. Working is carried on above the upper critical temperature while the iron is in the gamma, or face-centered cubic phase. Preferred orientation of the gamma grains no doubt obtains, but on cooling through the critical range the gamma iron changes to alpha or body-centered cubic iron and new grains form with approximately random orientation. Alpha iron which has been extensively worked below the critical temperature also develops preferred orientation. This is eliminated by annealing above the critical temperature. With the advent of the nickel stainless steels which retain the gamma phase at both high and low temperatures and silicon transformer steel as well as certain high chromium rustless irons which retain the body-centered cubic structure, hot and cold, the steel-working art faces a problem in orientation control. The same problem exists in the working of non-ferrous metals. Whether preferred orientation of grain fragments resulting from plastic deformation is desirable or otherwise, it is clear that it must for special purposes, at least, be put under control.

Surprises were also plentiful in connection with the types of fractures resulting from tensile tests of single crystals. The wedge fracture is a typical one in metals crystallizing in the cubic system. The orientation must be proper and two sets of intersecting slip planes of the same family cooperate to form the wedge. In one direction there is practically 100 per cent. reduction of diameter, and 90 degrees from this direction the diameter remains substantially unchanged. Other orientations give rise to a great variety of interesting fractures. In hexagonal metals there is a tendency for an original round section to flatten first into an elliptical cross-section and if elongation prior to rupture is considerable the final shape resembles a flat strip having a width approximately equal to the original diameter of the test piece. Again there may be an abrupt change in the shape of the cross-section as the result of mechanical twinning.

The extent of movement on a slip plane may be anything from a small fraction of an atom diameter up to more than 5,000-atom diameters. The smaller movements may only be detectable by some change in property, but the larger slips can readily be seen with a microscope. If a section of the metal is polished before deformation, the slip movement may produce a difference in level between the portions of the crystal on either side, thus facilitating detection with the microscope. Slip in many plastic metals has been studied in this manner. In some cases the slip lines are very straight and in others irregular. Some crystals show one predominating direction of movement and others exhibit sets of intersecting slips. Particularly in single crystal wires there is a tendency for the visible slip planes or slip bands, as they are called, to be evenly spaced. Some observers have reported that the spacing tends to be farther apart the higher the temperature of test for any given metal. The deformation does not proceed in a continuous manner but actually takes place in steps or jumps. Some single crystals and coarse-grained metals give out sound, known as a "cry," during deformation. This seems to be associated with the formation of mechanical twins. This suggests an internal shock when certain of the atoms make the slight shift necessary for twinning. Apparently external shock favors mechanical twinning because alpha iron which forms no twins on slow loading will do so on impact. Another surprise may be noted in this connection. Rosenhain found that if a piece of alpha iron is deformed, even a small amount by slow loading, and if then the deformation is continued by impact, no mechanical twins form.

Perhaps some of the greatest surprises in the study of the plasticity of single crystals of metals have been the unexpectedly small loads required to permanently deform them. It is not difficult to cold-draw copper wire until it has a tensile strength above 50,000 pounds per square inch. In this condition there may be very little permanent extension in bringing the load up to this value. A single crystal of copper, however, three quarters of an inch in diameter and long enough for a grip, can be bent without difficulty in the two hands. Hardening accompanying this deformation can be easily detected because greater force is required to straighten than to make the original bend, and a second bending is still more difficult.

It may be of interest to mention that tungsten filaments approaching single crystal structure are in general use because of their non-sag characteristics. At the relatively high operating temperature fine-grained filaments sag gradually as a result of their own weight. This general phenomenon referred to as "creep" is the subject of much study at the present time in connection with metals and alloys for use at elevated temperatures. In fine-grained tungsten filaments the gradual sagging has been traced to a sort of fluid flow at grain boundaries. The grain boundaries behave as if they were amorphous. Naturally a grain boundary displacement will force some kind of readjustment on the crystals themselves, and this may take the form of slip or transfer of atoms from one grain to another.

The rate of loading is an important factor in determining the extent and nature of plastic deformation in hot metals. Coarse-grained tungsten will resist sagging for hundreds of hours but will deform if the lamp is bumped. A fine-grained filament which sags badly in the course of time will resist deformation by bumping. These factors are now very well understood, and the structure of filaments and methods of mounting are controlled to provide resistance against both slow and rapid loading.

Studies of tungsten filaments have provided some useful information. It was observed years ago that hairpin-shaped filaments mounted horizontally had about equal resistance to permanent deformation at 1,350° C. no matter whether coarse- or fine-grained. Above this temperature the coarse-grained metal was superior and below it the fine-grained metal was best. The change in the sag resistance of single crystal tungsten was not great with increase in temperature. A filament which would not sag at 2,000° C. would not sag at, say, 2,500° C. In fact, the single crystal seemed to retain a definite but small elastic limit nearly up to the melting point. There seemed to be little change in the elastic limit down to, say, 1,600° C. We observe here the same characteristic as that just described in single crystal copper. It is not conceivable that the single crystal of copper which had an elastic limit approaching zero at room temperature could have had an appreciably lower elastic limit at say, 1,000° C., or some 80 degrees below its melting point. This same characteristic has now been observed in several other metals.

Realizing the extreme softness of single crystals of metals and the very slight change in hardness with change in temperature (at least within certain temperature limits) it now seems remarkable that the mere aggregation of differently oriented single crystals can result in the properties of poly-crystalline metals. The change in orientation alone does not seem adequate to account for all the results. Fine-grained metals not only possess markedly greater elastic limits and tensile strengths than the constituent crystals, but the properties vary with change of temperature in a different manner. For example, Sykes found that a molybdenum wire composed of a series of single crystals had the same tensile strength (30,000 pounds per square inch) in the temperature range 100 to 900° C., whereas a fine-grained molybdenum wire had its strength reduced from 115,000 pounds per square inch when tested at 100° C. to 70,000 pounds per square inch at 900° C. This discrepancy is still greater in molybdenum which has been worked below its recrystallization temperature and which in many respects simulates a very fine-grained condition.

The grain boundary effect is by no means confined to the boundaries themselves. This is illustrated nicely in Sykes' experiments in molybdenum wires, consisting of a series of crystals, each of which occupied the whole cross-section for a short distance. During the tensile test the grain boundary portions remained undeformed and the crystals necked down, the greatest reduction of area being nearly half-way between grain boundaries. This result is explainable on the ground that a change of orientation at the grain boundaries militates against the continuity of slip movement from one grain to another, but this simple interpretation does not negative the fact that fracture takes place as far from the grain boundary as it can, even though the distance be hundreds of thousands of atom diameters.

Another observation on single crystals of tungsten and molybdenum is that the elastic limit, which, as has been mentioned above, does not change much from the melting point down to relatively low temperatures, rises very rapidly on reaching a certain low temperature. A single crystal of tungsten can be bent at room temperature, but in liquid air the elastic limit is enormously increased and fracture occurs without any noticeable permanent deformation. Similarly, coarse-grained molybdenum more than trebles its tensile strength and the elastic limit is increased to an even greater extent on cooling from 100 to –190° C.

The more we study plasticity in metals the more wonderful does its nature appear. Hull attributed the brittle nature of crystals of non-metallic materials to the ionic nature of the atoms. In sodium chloride, for example, the sodium is supposed to be present as positive and chlorine as negative ions. On slipping one atom diameter positive ions are brought opposite other positive ions and negative ions opposite other negative ions with resultant repulsive forces and cleavage. There are supposed to be no, or very few, free electrons in non-metallic substances. Metals are supposed to contain free electrons. How many free electrons, what their positions or movements are or in what manner, if any, they contribute to plasticity are questions which are as yet unanswered. Physicists are doing a large amount of work in an effort to explain metallic conduction of electricity. Any progress which they make will prove helpful in the interpretation of plasticity. So far two extremes of electron arrangement have been proposed. The so-called classical theory assumes the free electrons present as a perfect gas and Lindeman has suggested the presence of free electrons at space lattice points different from the atom lattice points. The electron space lattice is supposed to be related to the atom space lattice. Also the idea that electrons simulate waves is being considered to explain metallic conductivity. Any of these conceptions can be used to account for the very low elastic limits of single crystals if we assume that the free electrons expand the atom space lattice.

Let us digress a moment to consider this point in more detail. Although high electric conductivity and high crystal plasticity are the common attributes of metals, it is clear that the two properties do not vary in the same way and not necessarily in the same direction. It may be more than a coincidence that the best conductors of electricity have face-centered cubic crystals, which is also the most plastic type of crystal. A single crystal of tungsten has higher electric conductivity in liquid air than at room temperature but has completely lost its plasticity at the lower temperature. Intermetallic compounds are good electrical conductors, but they may be non-plastic. Also, single crystals of intermetallic compounds may exhibit an extreme resistance to slip movement. Tungsten carbide, for example, is as hard as emery. Such facts would lead us to suppose that there is little relation between free electrons and plasticity.

The noble gas, argon, solidifies at –188° C. with a face-centered cubic space lattice. It is monatomic and the atoms should not be present in the space lattice as ions. It is transparent and practically a non-conductor of electricity. It would thus appear to have all the requirements for high plasticity, unless free electrons are important. A few years ago I tested solid crystalline argon for plasticity and found it to be brittle. It behaves like most nonmetallic crystals. While this does not prove that free electrons are essential for metallic plasticity, it, to my mind, strongly suggests some relationship.

Whether we like a mechanistic conception of atoms or not, they seem to behave in plastic deformation as if they are somewhat like solid spheres or similar shapes. May we not suppose that the atoms of argon in its crystal are so close together that slip movement can not take place without increasing the distance between planes? In other words, the high spots of the atoms on one plane so closely fit the recessions in groups of atoms of adjoining planes that slip is prevented. If we assume that free electrons in a metal are provided by neutral atoms, some or all of the atoms, depending on the number of free electrons, must be positively charged. This would provide one force tending to hold the atoms apart. The normal place for a free electron with its negative charge would be as far away as possible from other free electrons and between positively charged atoms. There is thus some reason to expect free electrons to increase the distances between atomic planes and there is reason to expect such increase to account not only for the great plasticity of metals but also for some of the peculiar observations with reference to temperature effects.

Taking single crystals of tungsten as an illustration, we can visualize the important potential slip planes so far apart just below the melting point that the atoms on one plane do not engage those on adjacent planes with consequent low resistance to slip. As contraction occurs on cooling, a temperature is finally reached at which the atoms approach the condition described for argon and, plastically, the crystal behaves much like argon. Of course the high attractive forces resulting in a high melting point must have a potent influence on the low temperature resistance to deformation and rupture. This is only one of many factors, however, which will require evaluation for the clarification of this subject.

The type of space lattice is apparently very important. Face-centered cubic metals, as, for example, gold, silver, copper, lead and aluminum, retain plasticity at very low temperatures, that is, below –190° C. Face-centered cubic iron retains plasticity at low temperatures better than body-centered cubic iron. In general, the body-centered cubic metals do not retain low temperature plasticity as well as face-centered metals. Hexagonal rhombohedral metals like bismuth and antimony become brittle at temperatures not far below their freezing points. I tested fine-grained and coarse-grained commercial wrought zinc in liquid air a few years ago and found no plasticity. I concluded that the hexagonal space lattice was not conducive to retention of plasticity at low temperatures. In attempting to gain additional evidence on this point, I tested a piece of commercial magnesium wire and was rewarded with another surprise to find it quite bendable at –190° C. Mankind may have cause to rejoice in the future because the two metals, aluminum and magnesium, which have most favorable densities for aircraft use, can endure the low temperatures encountered at high altitudes without becoming brittle.

It might now be concluded that the light weight atoms have some claim to superiority in the maintenance of low temperature plasticity. To spoil this idea as having any claim to generality, it is now found that beryllium, having a lighter atom than magnesium, becomes substantially non-plastic well above room temperature.

I wish now to describe my last two surprises. Dr. Schmid, of Germany, about two months ago gave us some single crystals of pure magnesium in wire form. Each crystal was about six inches long and three thirty-seconds inch in diameter. The first surprise was in learning of the minute effort required to bend one of these specimens. The elastic limit is so low as to be hardly measurable. By holding one end of a specimen a bend can easily be made by a gentle flip of the wrist. I was not prepared to find such a soft state in magnesium, notwithstanding experience with single crystals of many other metals. My last surprise came a few days ago when one of these magnesium single crystals was cooled to –190° C. in liquid air. It remained so soft that it could be bent with scarcely any effort. The elastic limit was so low that no substantial difference between the –190° C. and room temperature values could be detected without fine measuring instruments. I hope that this material will be tested for plasticity in liquid hydrogen, and if found to be plastic at that temperature it should be tested in liquid helium.

In closing, I wish to urge upon physicists the potentiality of the study of plastic deformation in metals as a means of unlocking some doorways to nature's secrets of the internal structure and properties of solids.

UNSETTLED QUESTIONS CONCERNING THE MATHEMATICS OF CHINA

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SINCE it is impossible within the reasonable limits of a paper of this kind to give a detailed survey of a subject so broad as mathematics, in a country so extensive as China, and throughout a period measured by more than forty centuries, it is necessary to set up rather definite limitations to be observed. These limitations are further conditioned by the fact that I write not as a sinologue but from the standpoint of a historian of mathematics in general. These circumstances are, I take it, by no means entirely unfortunate, since they impose upon me the duty of eliminating a large amount of information which can easily be found in printed articles and books in European languages, and afford the opportunity of calling attention to a few of those subjects relating to mathematics in China which require such investigation as only a thoroughly trained sinologue with a fair knowledge of mathematics and astronomy should undertake.

In the first place it should be said that the mathematics of the Orient in general has been concerned chiefly with puzzle problems which usually present but little difficulty when solved by modern algebra, these problems more often relating to mensuration or the calendar than to commercial practice. They rarely if ever touch upon the field of geometry as considered by the Greeks, and their theory of numbers is ordinarily very primitive. Trigonometry was developed to a considerable extent by the Arabs, to a slight degree by the Hindus, and apparently not at all, as independent of foreign influence, by the Chinese. As to developing any great mathematical theory, such as Euclidean geometry, a systematic study of conics, the theory of numbers (say of primes, perfect numbers, amicable numbers, or properties of numbers), the theory of algebraic equations, analytic geometry or the calculus, China never made even a beginning that is at all worth considering. She showed marvelous patience in detail, in attaining results with crude implements, and in constructing puzzle problems of no practical value, and in all this she was inspired by a pure love for a subject which was, for her, practical only to a slight degree. Until Western influence became apparent, her mathematics existed only in the age of childhood—not that children could solve the intricate problems she often set, but that the problems were childish in content, appealing solely to the puzzle instinct of the race.

While the native mathematics of China was thus immature in content, the early histories were equally so, and this is what makes the history of mathematics in that country difficult to write. History and mathematics alike were looked upon as means of entertainment, not as branches of knowledge scientifically conceived and constructed. If the modern historian seeks for aid in the "Shu Ching" ("Canon of History"), which tradition has asserted to be the oldest Chinese historical treatise available, he finds that the work is in part a late forgery and that it contains no information before the second millennium B. C. that is worthy of acceptance. Nor is this merely the dictum of modern historians, for already about the close of the Ming Dynasty (1368–1643) Huang

Tsung-hsi (1609–1695) wrote concerning the same work that it "is shown to be spurious by its unsound chronology, by its misunderstanding of ancient rites, geographical data, penal, governmental and religious practices, and its faulty use of words and sentences as we understand these from authentic records of antiquity."[1]

Even more scientific is the critical study made by Yen Jo-chü (1636–1704), the net result of whose investigations was to

> . . . clear the way for that splendid literary renaissance which flourished in the higher intellectual circles of China in the seventeenth and eighteenth centuries and is now known to us as the period of "Han learning"—so called because its proponents went back to the original Han texts and so revolted from the Sung interpretations upon which the current philosophy was based. Hereafter, not only the classic of history, but every one of the canonical books was brought within the scope of scientific inquiry. "There should be no data in ancient history," said Yen Jo-chü, "which are not subject to investigation."[2]

The opportunity for altering Chinese texts is seen to be particularly favorable when we consider this statement of Dr. Hu Shih:[3]

> Only a half dozen systematically written books have appeared in the last 2,000 years [in China]. Works of Chinese scholars are chiefly *Chi*, that is, collections; or *Tsa Chih*, that is, notes or fragments. . . . Scholars worked in patient devotion on minute minor points, without creative imagination to see wider relationship and discover new and more significant connections.

Modern skepticism concerning ancient texts is stimulated by the works of the late K'ang Yu-wei,[4] who asserted that all the texts which were claimed to have been found in the walls of the house of Confucius were spurious, and whose "more sober judgments have stood the test of time and form the basis of some of the best sinological scholarship of our day."[5]

The effect of such studies has been to reopen the entire question of the authenticity of ancient texts, and it is in this movement that we may hopefully look for aid in the next few years in determining which claims in the field of mathematics are valid, and which are not.

This being the attitude of Chinese scholars themselves, we are justified in seriously doubting, and indeed in denying, the validity of such assertions as that the emperor Fu Hsi invented the *pa kua* (the mystic trigrams still used in divination and seen in all parts of China) in the third millennium B. C. Equally doubtful is the tradition that, in the reign of his grandson Huang Ti ("The Yellow Emperor"), perhaps in the twenty-seventh century B. C., Tai-nao devised a sexagesimal system and Li-shu invented arithmetic and wrote the "Chiu-chang" ("Nine Sections") from which the later classic, "Chiu-chang Suan-shu" ("Arithmetic in Nine Sections"), developed. Still in the realm of tradition are the reigns of his successors, Yao, Shun and Yu, and the story relating to the sentence of death passed by Yao on the two astronomers Hsi and Ho for their failure to perform the ancient rites at an eclipse of the sun.[6] The tradition that in the reign of Yu there appeared to the emperor a divine tortoise upon the back of which there were found the *lo-shu* (the 9-called magic square) and the *ho-t'u* (another number arrangement used in divination) illustrates even more clearly the uncertainty that exists concerning all the ancient claims, for Hu Wei (1633–1714), a critical scholar, proved conclusively[7] that these diagrams (although not the names) originated with a certain Taoist priest named Ch'en T'uan who died in 989 A. D.[8] Thus a Chinese diagram, long supposed to be one of the earliest known in the field of numbers, is less than a thousand years old.

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[1] From a contribution by Dr. A. W. Hummel, in the Report of the Librarian of Congress for 1928, Washington, 1929, p. 304.

[2] *Ibid.*

[3] Lecture on Sinological Research at the Present Time, delivered at Peking (Peiping) before the North China Union Language School, June 12, 1925.

[4] "Hsin Hsüeh Wei Ching K'ao" ("The Forged Classics of the Wang-Mang Period"), 1891; "K'ung-tzu Kai Chih K'ao" ("Confucius as a Reformer"), 1867.

[5] Hummel, *loc. cit.*

[6] A partial eclipse was visible in North China in 2136, as modern computations show. This may serve to fix the date of Yao's reign.

Coming down to the historical period, the early writers stated that in the Chou Dynasty (1122–249 B. C.) Wên Wang, one of the rulers of the principality of Chou, while imprisoned by the cruel prince Chou Hsin for political reasons, wrote the great classic, "I-Ching" (I-king, "Book of Changes"), this being based upon the *pa-kua* and containing this diagram and the diagrams *lo-shu* and *ho-t'u*. As above stated, however, these last two diagrams are not earlier than the tenth century A. D. As to the book itself, there is no mathematical reason for believing that the *pa-kua* is not ancient. While the diagram contains the permutations of two things taken three at a time (repetitions allowed), this is simply a matter of arrangement easily worked out by a few rods, and does not necessarily require any mathematical reasoning. As to the *lo-shu* and *ho-t'u,* although the diagrams are relatively modern, there is also no reason why a description of them or even the diagrams themselves should not have been worked out three thousand years ago, there being no serious mathematics involved.

Without further multiplying the evidences as to the unreliability of the mathematical texts as set forth by Chinese scholars, it may be added that similar doubts have been expressed by such western historians as VanHee, Vacca and Loria, and by Sédillot, who, nearly a century ago,[9] spoke of the inextricable confusion in the texts sent to Europe by the early missionaries.[10]

Equally critical of the texts is our leading historian of eastern Asiatic mathematics, the Japanese scholar Yoshio Mikami,[11] who confesses that, as regards China, "we are utterly at a loss when we try to investigate the growth of the science in remote antiquity, for old documents or records are entirely wanting."

The question of our debt to ancient and medieval China, in the field of mathematics, therefore resolves itself largely into that of textual criticism and of finding more source material. We have relatively little trouble with European texts, for scholars can usually detect at once any interpolations of consequence, either from the handwriting or from linguistic changes. It is interesting to know that the Chinese are already carrying on the work so well begun in the seventeenth and eighteenth centuries by scholars like Huang Tsung-hsi and Yen Jo-chü, and that we may hope for authentic texts, in due time, of the mathematical treatises of the past or of the fragments that exist. The outlook is encouraging for such work on the part of Western sinologues, as witness the critical studies of Confucian texts now being made by Dr. Arthur W. Hummel, of the Library of Congress.

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[7] In his "I T'u Ming Pien" ("Exposition of the Diagrams in the Classic of Changes"), published in 1706.

[8] Report cited, p. 305.

[9] "Matériaux pour servir à l'histoire comparée des sciences mathèmatiques chez les Grecs et les Orientaux," Paris, Vol. I, 1845; Vol. II (consecutively paged), 1849, p. 564. His printed works on oriental mathematics began with the date 1834.

[10] Il semble que les missionnaires européen, curieux de nous les faire connaître, et sans examen tous les récits qui rantraient, à quelque titre que ce fût, dans le domaine de la science. Aussi résulte-t-il de cette absence complète de méthode, un pèle-mêle inextricable de notions plus ou moins obscures, et de faits contradictoires."

[11] "The Development of Mathematics in China and Japan," Leipzig, 1913. Pages 1–155 are devoted to China. A list of texts, including most of those needing investigation, was published in 1885, edited Ch'en Wei-ki. For a translation and comments by Père Van-Hee, S. J., see *Amer. Math. Monthly*, Vol. 33, p. 502.

Having stated the difficulties, and the hope which the future offers that the chief ones may be removed through textual criticism, I wish to mention a few of the problems about which historians of mathematics need special assistance. Laying aside the questions relating to the I-ching as mathematically of little importance, I begin with the first of the classics in this field.

Is it not possible to date more precisely the "Chou-pei Suan-ching" ("Chou-pei arithmetical classic") and the various interpolations and additions of which we have evidence? The book is known to us only through commentaries of uncertain date, one of which is not earlier than the second century A. D., although the well-known dialogue which it contains seems to be of the twelfth century B. C. Since this work is said to have contained the 3–4–5 relation of the right triangle, with geometric diagrams, although no general statement of the Pythagorean theorem, it is important to know the validity of such a reference some six centuries before Pythagoras lived. Evidently that part of the dialogue which relates to the sun's orbit at the winter equinox, and which shows the use of 3 for π, is a late interpolation, but about how late? It makes mention of Lü-Shih (Lü Pu-i), a minister in the reign of Ch'in (third century B. C.), and asserts that he gave the year as $365\frac{1}{4}$ days and that the circle had $365\frac{1}{4}$ parts (degrees). If authentic, these statements have a bearing not only upon the history of the calendar but upon the relation of 360 degrees in a circle to the number of days in the ancient year, which seems doubtful.

Similarly, we need a critical study of the second great mathematical classic of China, the "Chiu-chang Suan-shu" ("Arithmetic in Nine Sections"). While it seems fairly certain that this was first written before the "burning of the books" by order of the powerful despot Shih Huang Ti ("The First Emperor"), who ascended the throne in 246 B. C., and in whose reign the Great Wall was completed, the original form of the text seems to have been lost rather through the efforts of commentators or copyists than through the failure to preserve copies from destruction by the emperor's edict. Our present knowledge of the work comes largely from Chang T'sang (*c.* 250–152 B. C.) and from Ching Ch'ou-ch'ang, who further revised it *c.* 50 B. C. In particular we should like to know whether the text is properly interpreted as stating that counters (probably rods but not the modern *suan pan*) were used by the original writer, and that he employed a method of solving three linear equations which involves essentially the simplification of a determinant by the subtraction of columns and their multiples, and hence the use of negative numbers. Mathematically considered, this latter feature in the solution is doubtful, whereas the former one is probable. The work contains the Rule of False Position (*the Regula falsae positionis* of the medieval European writers), and this too may possibly be genuine in a work of the first millennium B. C., since the Egyptians had long been familiar with the general idea; but proof of its authenticity is none the less important. It may also be observed that certain of its problems are such as are found in India in the seventh century A. D., raising the question of the reliability of the text and illustrating the interchange of ideas among races and regions.

The next mathematical treatise of importance, the "Sun-Tsŭ Suan-ching" ("The Arithmetical Classic of Sun-Tsŭ"), was formerly assigned to the sixth century B. C., which would have been very early for certain of its mathematical features. The learned Tai Cheng (1722–1777), however, showed[12] that the language used rendered it impossible that it should have been written before the reign of Ming-Ti (58–75 A. D.). What needs further investigation, however, is Sun Tsŭ's method of solving simultaneous linear equations and his work in indeterminate equations, or in problems which we would now solve by these means. Viewed from the standpoint of the history of mathematics, each of these is doubtful, although each is possible. Aside from these features the work contains little that is not found in the "Arithmetic in Nine Sections."

It is, of course, possible that the considerable number of problems in indeterminate analysis found in the early Chinese texts are authentic and represent a kind of mathematical trait of the people. On the other hand, knowing the unreliability of the early texts, we may reasonably doubt their antiquity and hope for a more careful study of the texts than has yet been given. In particular, it is desirable to know if they are certainly earlier than the eighth century, when I-hsing (683–727), a Buddhist priest of the T'ang Dynasty (617–906), wrote on the *t'ai-yen shu*, a method of indeterminate analysis. In his case, too, since he knew Sanskrit, an interesting question arises as to how much of his *T'ai-yen* Calendar and his work in analysis was due to Indian sources.

It is said that, in the same dynasty, a Buddhist monk, I Hang, gave a problem relating to the permutations of grains of wheat on a chessboard. This leads to very large numbers and raises a question that occurs much earlier in the history of oriental mathematics—that of counting by myriads (10,000's) as used by the Greeks, Hindus and Chinese alike. It would form an interesting study to see how this device spread, perhaps through the Greek colonies (327 B. C. and later), or possibly from some common (Sumerian?) source.[13]

No further mathematical questions need concern us for nearly three centuries after the death of I-hsing. There then appeared a problem in a work by Ch'ên Huo (died 1075), president of the Astronomical Board, that deserves investigation as to its authenticity. It is to find the number of casks of wine piled in the form of a truncated pyramid having 2^2 kegs in the top layer and 12^2 in the bottom layer, the number of layers being 11. The problem is simple and its interest lies in the fact (1) that a rule for its solution seems to have been known in the "Arithmetic in Nine Sections," but not generally used thereafter; (2) that, if applied to a general case, it involves the summation of a power series; and (3) that it is similar to the problem concerning the piling of cannon balls, which becomes prominent in the sixteenth century in Europe. The questions here involved may lead to a determination of the authenticity of the text, and they suggest enough doubt to justify careful investigation.

Of all the works needing critical study those of the thirteenth and fourteenth centuries are the most prominent. This is not so much because of doubts as to their authenticity, for they are late enough to make changes in the text more readily detected, but because of the obscurity of certain statements in the works of three mathematicians, Ch'in Chiu-shao, Li Yeh and Chu Shih-chieh. These writers, living widely separated from one another, all devoted themselves to the solution of problems requiring more ingenuity than most of those of their predecessors in the fields of algebra and intuitive geometry.

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[12] Mikami, *loc. cit.*, p. 25.

[13] On the chessboard problem see G. Vacca, "Note Cinesi," *Rivista degli studi orientali*, Vol. VI, p. 135. The problem is not the familiar medieval one of the number represented by the sum of a geometric series.

Ch'in Chiu-shao[14] wrote, in 1247, the "Su-shu Chiu-chang" ("Nine Sections of Mathematics"). In this he made use of the *t'ai-yen ch'in-i shu,* or method of indeterminate analysis which is found in the work of Sun-Tsŭ already mentioned and of various other later writers. The work consists of 81 problems and in it he gives some interesting cases in the theory of numbers, areas, series, and (what is most important) the solution of numerical higher equations by a method which, in its basic principles, seems to be that which Horner first used in England in 1819, but about which (in the Chinese form) there is considerable doubt. Indeed, in general, some very critical questions have been raised respecting Ch'in Chiu-shao's work as a whole. For example, he gives a certain problem in measurement; from this he obtains a numerical equation of the tenth degree which is very much more difficult than the cubic equation which he might have used had he been even a mediocre geometer. He then states that the root is 9, which does not satisfy the equation at all. What, then, was the trouble? Did some copyist blunder, or is it that Ch'in did not himself know what he was doing?[15]

He also states a numerical equation of the fourth degree and gives a few numbers used in the solution. Upon these is based the claim that he anticipated Horner's Method, but this is little more than a conjecture.[16]

It is, of course, apparent that neither Ch'in nor Horner could be indebted to the other, and the solution is so abridged as to make it very doubtful whether there is really any relation whatever between the two methods.

The second of the Chinese algebraists above mentioned was Li Yeh (1178–1265) who wrote (1248) the "T'sê-yüan Hai-ching" ("Sea Mirror of the Circle Measurements") and (1259) the "I-ku Yen-tuan." In these works Li gives a series of problems and shows how they lead to algebraic equations, but without paying much attention to solutions; whereas his contemporary, Ch'in Chiu-shao, was concerned with the solutions, without showing much interest in the transfer from problem to equations. The work of each of these scholars was therefore the complement of that of the other.[17] There is, therefore, less need for a critical study of Li Yeh's work, unless it may be to find if his problems, which give every appearance of being original with him, are really so.

The third of the thirteenth-century algebraists was Yang Hui. In his works of 1261 and 1275 he shows much skill in summing progressions, in solving linear equations, and in attacking from the geometric standpoint the solution of a biquadratic equation. Algebra had by this time advanced far enough in China to permit of most of this work, but the question of the biquadratic needs careful consideration, especially with respect to Arab influence. It is quite probable that such influence may have resulted from the interchange of knowledge in several ways as, for example, between the astrologers in the court of Genghis Khan and those in the regions which he conquered.

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[14] Ts'in K'ieou-Chao, as transliterated by Père VanHee.

[15] The question was raised, as also the next one, by Professor Gino Loria in the *Bollettino della Mathesis,* April, 1920, and was further considered by Professor R. B. McClenon in THE SCIENTIFIC MONTHLY, June, 1921, p. 517.

[16] For a conjectural restoration of the solution and the statement that "we cannot but be reminded of the celebrated method of Horner," see Mikami, *loc. cit.*, pp. 74–78; and a "remark" in *Archiv der Mathematik und Physik,* XV (3), p. 68.

[17] As to the earlier Chinese writer from whom Li Yeh obtained some of his problems, see Père VanHee, S. J., in *T'oung-pao,* Vol. XIV, p. 539.

As the thirteenth century was changing to the fourteenth the work of these three scholars was advanced in a notable degree by Chu Shih-chieh.[18] He wrote two treatises (1299, 1303) which represent the greatest advance in Chinese mathematics before the western influence made any distinct impression upon this part of the world. This was not so much because of their originality as because of their later influence in the Far East. They may be said to represent an improvement in method rather than in ability to solve equations, but this improvement was precisely what was needed to complete the work of the thirteenth century. It should also be observed that Chu constructed an arithmetical triangle by which the coefficients of the binomial series can be found, speaking of it as already known. This method is found in Baghdad at the end of the eleventh century, and may have come thence to China.

Such a possibility raises a further question as to the general exchange of mathematical knowledge between China and the South and West. This has often been considered in a general way, but specifically, as regards the details of the science, much remains to be done. The opportunities with respect to India and China were many. Those relating to China and both Persia and the Iraq region were less numerous. We are all aware of many intellectual contacts of China with her neighbors, of the influx of Buddhism, of several notable visits of Chinese scholars to India, of the translation of Sanskrit works into Chinese, of the several conquests extending to Turkestan and northwest India, and of the coming of the Nestorians, but what the specific effects were upon mathematics has yet to be discovered, and the search is by no means hopeless.

As to the introduction of Western mathematics from and after the time when the Jesuits arrived, this is too well known to need comment. We have only to consult H. Cordier's work, "L'Imprimerie Sino-Européenne en Chine" (Paris, 1901), or the summary by Père VanHee, S. J., in the *T'oung-pao* (2 Serie, Vol. XV, p. 111) to understand how great was the influence of Europe in the fields of algebra, trigonometry, and mensuration.[19] Here the question of originality hardly enters, since the indebtedness to western writers is apparent throughout.

Summarizing the matters to be considered and omitting names and dates, we need the help of expert sinologues upon the following points:

1. The authenticity of ancient texts, determined by a new and scientific study of the most (apparently) reliable manuscripts and block books extant.
2. The approximate dates of these texts and of any interpolations and commentaries, determined in the same way.
3. The evidences of foreign influence in such matters as the calendar, problems, and methods of treatment of equations, including those of the indeterminate class and the approach to determinants.

In all this work the historian of Western mathematics can assist in stating probabilities as to dates, these being based upon his knowledge of European, Indian, or Arabian achievements; but the other questions involved are for the experts in the study of ancient Chinese texts.[20]

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[18] The Tschu Schi Kih of Cantor's *Geschichte der Mathematik*, 4 vols., Leipzig, 1880–1908, with various revisions. Père VanHee spells the name Tchou Che-Kie.

[19] See also his articles in the *Amer. Math. Monthly*, Vol. 33, pp. 326 and 502.

[20] One very helpful movement in this direction is seen in the recent (1930) establishing of *Études Chinoises* by Père VanHee. It announces the fact that two books on the history of Chinese mathematics are in course of preparation.

SOYA FLOUR AS A NATIONAL FOOD

By Dr. A. A. HORVATH[1]

> If one will contrast the present conventional breakfast, which is almost a meatless breakfast, with the breakfast of two decades ago, one will realize that meat has been replaced by cereals, sugar, milk and fruit.—*Taylor.*[2]

According to C. Alsberg,[3] "A national dietary which consisted entirely of primary foodstuffs, that is to say, a wholly vegetable diet, would be one that could be produced with the minimum of labor and the minimum of land."

Professor Taylor[4] has calculated that "The United States could support some 500 million people on a largely vegetarian diet, in which cereals and legumes would form the chief sources of protein, with only such animal products as could be secured from inedible residues and forage on land not adapted to the raising of primary crops."

The experience of the Chinese people is a good example that even an entirely vegetarian diet is adequate in every respect if supplemented by the use of soybean products.

The soybean is a plant of very early cultivation in China. It is mentioned in the "Ben Tsao Gang Mu," the ancient Materia Medica, written by the Emperor Shen Nung in the year 2838 B. C.

When one realizes that these beans are, and have been for upwards of one hundred generations, the principal source of protein in the Chinese diet, and when one further considers the sustained hard manual work that the Chinese are capable of, as well as their mental virility, and the high state of their culture in a period when Europe and America were barbarians, it will be understood that the question of this diet is worth studying to introduce it in the dietary of this country.

It took 300 years after the introduction of the potato into Europe for its use to become general, but in these days of wide publicity and the public's more intelligent appreciation of food values, it should take but a very short time for the use of soya meal to become universal since it has five times the calorific value, twenty times the protein value, and two hundred times the fat value of potatoes. It should become a national food in every sense.[5]

In the United States, over 3 million acres are under the cultivation of this bean, and there are indications that it is gaining popularity as a food article, due to its high nutritive value and the strong support given it by various scientific and business organizations and the U. S. Department of Agriculture with the Bureau of Home Economics. The American Soybean Growers Association is also doing its best to promote interest for this outstanding seed.

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[1] Till recently, of the Rockefeller Institute for Medical Research, Princeton, N. J. (Former head of the Soybean Research Laboratory at Peking Union Medical College, Peking, China.) "The Soybean as Human Food," a monograph published by the Bureau of Industrial and Commercial Information, Ministry of Industry, Commerce and Labor, National Government of the Republic of China, 2d ed., 1930, Shanghai; *J. Biol. Chem.*, lxviii, 343, 1926; *Jap. Med. World*, vii, 105, 1927, and viii, 1, 1928; *Amer. J. of Physiol.*, xciv, 65, 1930.

[2] Of the Food Research Institute, Stanford University. From an article entitled "Consumption, Merchandising and Advertising of Foods." *Harvard Business Review*, II, 283, 1924.

[3] Director of the Food Research Institute, Stanford University. From an article entitled "The Effect of Scientific Food Consumption in Increasing Wealth." Ann. American Academy of Political and Social Sciences, cxv, 1924.

[4] From an article entitled "The Future Food Supply of the United States." *Bull.* New York Academy of Medicine, November, 1927.

[5] According to Pearl, in this country the average diet of a few years ago, as ingested, contained 114 gms of protein, 127 gms of fat and 433 gms of carbohydrates, corresponding together to about 3,424 calories per adult man per day. The soybeans seem to become a valuable source of cheap protein and fat, as predicted fifty years ago by Professor Haberlandt.

The composition of common American varieties of soybeans is the following:[6]

Variety	Moisture, per cent.	Protein, per cent.	Fat, per cent.	N-free extract, per cent.	Fiber, per cent.	Ash, per cent.
Mammoth	7.49	32.99	21.03	29.36	4.12	5.01
Ito San	7.42	34.66	19.19	27.61	5.15	5.97
Haberlandt	8.67	36.59	20.55	24.41	4.00	5.78
Guelph	7.43	33.96	22.72	25.47	4.57	5.85
Midwest	8.00	35.54	19.78	26.30	4.53	5.85
Kingston	7.45	36.24	18.96	26.28	4.79	6.28

The soybean is remarkable for its richness in protein, fat and mineral matter, as can be seen by comparison with other foods:

	Protein	Fat
Lima bean	18.1	1.5
Eggs	14.8	10.5
Lean meat	19.2	10.7
Whole wheat	12.2	1.7
Milk	3.20	3.50

The soybean contains double the amount of the protein and calories present in beefsteak.

The nitrogen-free extract of the soybean is composed chiefly of dextrin (3.14 per cent.), galactan (4.86 per cent.), pentosan (4.94 per cent.) and sucrose (3.31 per cent.). Starch is present only in traces,[7] while in cereals starch is the chief ingredient.

The soybean protein (glycinin) is a complete protein containing all the essential amino-acids necessary for the building up of the proteins of the human organism. Glycinin is very similar in properties to the casein of milk, being coagulated by acid. According to Osborne and Mendel,[8] the proteins of the soybean, unlike those of the other leguminous seed, are adequate for promoting normal growth. A soybean diet increases the protein content of the blood (Horvath).

Rose and MacLeod[9] demonstrated that the human organism is able to store three times as much nitrogen from a soybean food as from meat.

According to Dr. Tso,[10] for use in feeding babies, the soybean proteins are comparable to cow's milk protein. Recently forty babies were successfully fed at the Department of Pediatrics, Harvard Medical School, for a period of two months and more, a diet with soybean flour as the sole source of protein (Hill and Stuart).

According to Dr. Kupelwieser,[11]

> Soya flour proved to be a protein source of hitherto unparalleled cheapness. That we need have no hesitation in making use of it, and that with it the white race can also cover a very considerable part of its protein requirements, has been fully demonstrated by nutrition experiments extending over a long period carried out on children, the half of whose daily protein requirements was given to them in the form of soya flour.

Refined soybean oil has been studied with other oils in a series of experiments carried on by the office of Home Economics of the U. S. Department of Agriculture, and found to compare favorably with the more common culinary table oils with respect to the thoroughness with which it can be assimilated.

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[6] Data of the Tenn. Agr. Exp. Sta.

[7] It makes the soybeans a valuable food for diabetics. See von Noorden; and Friedenwald and Ruhräh, *Am. Jour. Med. Sci*, cxl, 793, 1910.

[8] Of Yale University. See *Jour. Biol. Chem.*, xxxii, 369, 1917.

[9] Of Professor Sherman's Nutrition Laboratory, Columbia University. *Jour. Biol. Chem.*, lxvi, 847, 1925.

[10] *Chinese Jour. of Physiol.*, iii, 353, 1929.

[11] Of the University of Vienna.

Lecithin (a phospho-lipoid) is present in the soybean to an extent of 1.64 per cent. Lecithin is an important constituent of all organs of the human body and especially of the nervous tissue, the heart and the liver. The percentage of lecithin in those organs raises while on a soybean diet (Horvath).

Cephalin (a phospho-lipoid) was found in the soybean by Levene and Rolf.[12] Cephalin forms an essential part of the substance of the brain.

The ash of the soybean is alkaline, while the ash of other cereals is acid (Nuzum, Osborne and Sansum).[13] The ash is rich in phosphates (31.52 per cent. of P_2O_5). A soybean diet raises the phosphorus content of the blood (Horvath).

The calcium content of the soybeans is 0.26 per cent., while that of cow's milk is around 0.16 per cent. They contain an excess of fat in regard to the ratio calcium: fat required for optimal absorption and metabolism of calcium salts.[14] If supplemented by wheat flour, reducing the percentage of fat in the mixture, the soybean diet keeps the blood calcium at a normal level (Horvath).

So far as we are aware, the soybean is the only seed which contains both the water-soluble and the fat-soluble vitamines (Osborne and Mendel; Daniels and Nichols).[15] The presence of vitamines A and D was demonstrated particularly by Hornemann,[16] and the vitamine A content recently by Scheunert.[17] Both vitamines B[18] (B_1 and B_2, otherwise termed F and G) were found. The fertility vitamine E is also present (Daniels and Hutton)[18a], as well as vitamine C. A diet of germinated soybeans increases the clotting capacity of the blood (Horvath).

It can be seen that, from the point of view of its chemical constituents, its physiological value and its richness in vitamines, that the soybean occupies an outstanding place among the foodstuffs.

Since it is quite difficult to boil soybeans to softness, they were used by the Westerners mostly in the form of flour, 20 per cent. of it being mixed with wheat or rye flour (or both) in the manufacture of bread, and good results were recorded.

In this country, Johns and Finks,[19] using a soybean bread,[20] found "that the mixture of soybean and wheat proteins is much better utilized than the wheat proteins alone. Comparisons show that for the same amount of food consumed, *the soybean bread diets are about two or three times as efficient as the wheat bread diets.*"

In Italy, extensive studies along this line were conducted on men by Professor Ducceschi[21] of the Committee for the Study of the Soya.[22]

Six normal individuals were kept by Ducceschi for a period of from 4 to 6 days on a sole diet of a 10 per cent. soybean bread.[23] The average daily ration was 739 gms of bread per capita with a protein content of 97.3 gms and 2,940 calories.

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[12] *Jour. Biol. Chem.*, lxii, 759, 1924–25.

[13] *Arch. Int. Med.*, xxxv, 492, 1925.

[14] As is the case also in excess fat milk.

[15] *Jour. Biol. Chem.*, xxxii, 91, 369, 1917.

[16] *Z. Unters. Nahr. u. - Genussmittel*, xlix, 114, 1925.

[17] *Fortschritte der Landwirtschaft*, 3 Jahrg., H. 24, 1928.

[18] The anti-beri-beri and anti-pellagric vitamines.

[18a] *Jour. Biol. Chem.*, lxiii, 143, 1925.

[19] Of the Bureau of Chemistry, U. S. Department of Agriculture. *Amer. Jour. Phys.*, lv, 455, 1921.

[20] A 15 per cent. soybean bread of "war flour" contained 13.3 per cent. protein. They used up to 25 per cent. of soybean flour for bread.

[21] Director of the Physiological Institute of the University of Padova, Italy. Atti della Societa Medico-Chirurgica di Padova, Italy, 1927.

[22] Founded by order of Premier Mussolini.

[23] Military whole wheat flour and 10 per cent. extracted soybean flour (54.89 per cent. of protein in dry substance). To supplement the shortage of fat, 25 to 30 gms of butter were used with the bread.

The utilization of this 10 per cent. soybean bread was:

Total absorption of the dry substance	93.72	per cent.
Total absorption of the calories	93.84	" "
Nitrogenous substance	83.90	" "
Fat	94.13	" "
Carbohydrates	96.59	" "
Mineral substance	68.60	" "

The conclusion was:

> The research performed on human individuals on the intestinal utilization of the nitrogonous substance and its relationship to the metabolism of nitrogen during a sole diet of bread containing 10 per cent. of soybean flour demonstrated that this bread was in appearance, digestibility and utilization equal to a bread from only wheat of best quality, having the advantage of containing a higher per cent. of nitrogenous substance.

A sole diet of a 20 per cent. soybean bread[24] was tested on two normal individuals for a period of five days consisting of 831.5 gms of bread, containing 127.6 gms of protein and 3,272.8 calories per capita per day.

The utilization of the 20 per cent. soybean bread was:

Total absorption of the dry substance	92.41	per cent.
Total absorption of the calories	92.48	" "
Nitrogenous substance	80.30	" "
Fat	95.70	" "
Carbohydrates	97.01	" "
Mineral substance	62.53	" "

Although the assimilation is in this case slightly below the preceding, the figures lie, according to Ducceschi, within the satisfactory limits for white bread.

The general conclusion of Professor Ducceschi can be quoted as follows: "The soybean flour, if added to bread or other nutritive food preparations, is going to become a valuable supply of cheap protein for the alimentation of the people."

Before the war, around two tons of extracted soybean flour[25] were used daily by the bakeries in Hamburg, Germany, for bread and, since 1920, a 10 per cent. soybean bread is supplied in Hamburg to hospitals, asylums, and other public establishments. To quote the authoritative words of Professor Neumann,[26] "The heads of the hospitals were unanimous in their praise of this bread, since there was nothing to wish for in regard to taste and utilization."[27]

The manufacture of a similar 10 per cent. soybean bread was begun in 1920 also in the coal-mining and industrial districts of Bochum, Dortmund and Düsseldorf in the Ruhr (Germany). Here the soybean bread is of particular importance for greater efficiency of muscular work, due to the high physiological value of its protein, the richness in phosphates, and the alkalinity of its ash. It was shown recently that the administration in the morning of phosphates on days of hard exertion markedly relieves fatigue.[28] And it is a well-established fact, too, that muscular work lowers the alkaline reserve of the blood by floating the blood with lactic acid, etc. Ordinary bread (wheat, rye, and others) is acid forming in itself and the addition of the physiologically alkaline soybean flour to it is thus contributing to higher efficiency of the work.

Complete metabolic experiments regarding the utilization by men of soybean bread as a sole diet (500 to 750 gms of bread) were conducted recently (1928) by Professor Neumann, director of the Hygienic Institute in Hamburg, on ten normal individuals for periods of from 4 to 5 days. Various flours were tested. A 20 per cent. bread baked from extracted soybean flour (of the Hansa Mill) showed 79.61 per cent. utilization for protein, 95.91 per cent. utilization for carbohydrates and 91.75 per cent. utilization for calories.

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[24] Supplemented by 25 to 30 gms of butter, as in the previous experiment, since the soybean flour was deprived of oil by extraction.

[25] Of the Hansa Mill, Hamburg.

[26] Director of the governmental Hygiene Institute in Hamburg, the largest institute of its kind in Germany. *Archiv für Hygiene*, ic, 1, 1928.

[27] The addition of 10 per cent. extracted soybean flour to a wheat-rye flour (60 per cent. rye and 40 per cent. wheat) of 70 per cent. milling yield raises its protein content from 6 to 8 per cent. 15 per cent. soybean flour brings the protein content to 10 per cent.

[28] Muscular work is accompanied by a loss of phosphates derived from the muscular tissue.

Numerous soybean flours have been on the markets of Europe and the United States for the last fifteen years, but none of them, with one exception,[29] can claim to have met with real success for the following reasons:

1. *Whole ground bean flour* has a peculiar beany taste, and can not be kept or transported on account of its rapid deterioration. It acquires in a very short time a bitter taste and a repugnant flavor. Its oil turns rancid and its fat soluble vitamines (A and D) are destroyed. Such a deteriorated flour, if ingested in any form, is toxic, causes disturbances of the digestive tract and destroys the fat soluble vitamines ingested with other foods (Fredericia). It was found by experiments on albino rats that the longevity on whole soybeans is greater than on ground whole soybeans.

2. *Soybean flour prepared from press cake* is subject to the same criticism, since the press cake still contains 5 to 8 per cent. of oil. Such a flour deteriorates even more rapidly, due to the excess of moisture and the more thorough breaking up of the bean cells.

3. *Extracted soybean flour* is not subject to rancidity more than ordinary wheat flour, since most of the oil is removed. But such a flour has the peculiar beany taste and is deprived of the highly valuable constituents—the lecithin and the vitamines A and D.[30] Besides, the solvent used in denaturing the soybean protein and the removing of the solvent by steam is often incomplete, thus rendering the extracted flour toxic.

The market flours obtained either from whole soybeans, press cake, or extraction meal, all possess, in addition, the disadvantage of being milled from unshelled beans. And it was recently shown by Neumann[31] that the presence of shells in soybean flour reduces the longevity to 70 per cent. in comparison with a diet of shelled beans.

Professor Neumann's authoritative conclusion is that "*Soybean flour, either for use in the kitchen or for baking of bread, must be manufactured exclusively from shelled beans.*"

The problem of eliminating the beany taste and peculiar odor of the soybean without injuring its valuable qualities has been occupying the attention of a number of scientists and industrialists. The majority performed nothing but the simple operation of roasting soybean flour from press cake, and felt justified to put it on the market labeled as "health flour." The writer noticed, in 1923, that the water in which the beans were soaked contained a large part of the odoriferous substance, and that a part of the beany taste was eliminated during germination. These observations indicated that the specific substances are located somewhere in the superficial layers of the bean cotyledons, and that germination can be used for improving the taste of the bean and consequently bean flour. But it was found rather difficult to obtain a uniform product of a standard quality, as the manufacturing expenses were high, and the flour dark in color.

Recently the problem of the utilization of the valuable constituents of soya for human food has entered on a new phase, for Berczeller,[32] working in Vienna, has devised a

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[29] Berczeller's soybean flour.

[30] They are all extracted with the oil.

[31] On mice.

[32] Professor of the University of Vienna, Austria. *Biochem. Z.*, cxxix, 318, 1922.

> special process of milling, combined with fractional distillation, whereby the obnoxious constituents can be removed and a meal of high nutritional value obtained. This special soya meal forms a slightly yellowish flour of agreeable and appetizing appearance and a faint almond-like taste. It differs from the product obtained by the simple milling of the bean in its complete freedom from bitter flavor and its capacity of being stored practically indefinitely without turning rancid (Professor Parsons).[33]

A sample of Professor Berczeller's patented soybean flour "Soyolk" was analyzed by the writer and gave:

Water	7.37	per cent.
Fat	19.64	" "
Lecithin	1.38	" "
Protein	42.12	" "
Nitrogen-free extractives	23.40	" "
Crude fiber[34]	1.33	" "
Ash	4.76	" "
Total	100.00	per cent.

According to Dr. Kupelwieser,[35] 1 kg of "Soyolk" flour is equivalent in caloric value to 3.63 kgs lean boneless beef, or to 57 eggs, or to 6.5 liters of cow's milk, while, in respect to protein contents, 1 kg soyolk flour is equivalent to 2.05 kgs lean boneless beef, or 67 eggs, or 13.7 liters of cow's milk.

Berczeller succeeded in freeing the soybeans of their specific taste, and in retaining their fat in a condition in which it is not liable to turn rancid, as stated by Professor Durig[36] and others. This phenomenon can perhaps be explained by the elimination during the process of distillation of some volatile fatty acid acting in untreated beans as a catalyzer for the oxidation of oil.

Eggs and fish roes are perhaps the principal source of lecithin[37] (organic phosphorus) but "Soyolk" flour contains more of this valuable constituent than any other vegetable food, and, when one considers its price, it will be found that it is a cheaper means of obtaining this nerve and brain food than eggs. One pound of "Soyolk" flour contains lecithin equivalent to six eggs.

Berczeller's flour does not produce obesity in spite of its high fat content—a fact due to the peculiar quality of its lecithin[38] and oil, which enables the organism to utilize them in the organs and tissues instead of storing them in fat depots. This was confirmed by the writer who found a higher lecithin content in the heart and liver of animals fed Soyolk flour.[39]

Soyolk flour contains also the valuable fat-soluble vitamines A and D, which are deficient in the food of the white race. Recent studies by Seifried have shown that if the diet is deficient in vitamine A, a degeneration in the glands of the body is taking place. The mucosa of the nasal cavity and respiratory tract is finally desquamated, giving way to a secondary bacterial invasion, resulting in severe rhinitis, sinusitis, tracheitis, bronchitis, etc. Conjunctivitis is also very common. Similar changes are observed also in other vital organs. Professor Van Leersum[40] found in vitamine A deficiency calcification of the epithelium of the kidney.

Haugue found recently an indication of the existence of a close physiological relationship between the yellow color and the formation of vitamine A. The yellow color of Berczeller's Soyolk flour from this point of view is a highly valuable quality.[41]

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[33] From an article entitled "The Use of the Soy Bean in Human Nutrition" in *The Lancet*, ccxii, 267, 1927.

[34] The low fiber content is due to the removal of the shells from the beans before their being treated.

[35] Of the University of Vienna.

[36] Director of the Physiological Institute of the University of Vienna.

[37] Milk and butter are deprived of lecithin.

[38] Hesse found that lecithin of vegetable origin does not produce obesity. And Bloor showed that lecithin is in charge of the transport of fat in the body.

[39] Professor Kafemann is recommending since 1913 the use of soybean flour for treatment of alcoholism. This investigator showed that the heart muscle of alcohol-intoxicated animals contained only one half of the amount of lecithin present in the hearts of normal animals. *Allgem. Med. Centr. Zeit.*, No. 41, 1913.

[40] Of the Netherlands Institute of Nutrition, Amsterdam, Holland.

The presence of vitamine A in Soyolk flour renders it particularly valuable for engineers, miners and factory workers exposed to sudden changes in temperature, dust, excess moisture, etc., as it increases their resistance to the diseases of the respiratory tract and particularly to sinus troubles. On account of its vitamine D content, Berczeller's Soyolk flour is of special value for "indoor" persons who are deprived of the beneficial effect of the ultra-violet radiation of the sun (working in underground galleries, under roofs, in buildings with windows of ordinary glass, etc.).

The physiological alkalinity of the ash of Soyolk flour and its richness in phosphates renders it highly valuable for miners and hard muscular work in general, relieving fatigue and thus increasing their efficiency.

Professor Van Leersum (Amsterdam) proved, in 1929, by direct experiment that Berczeller's Soyolk flour is rich in the vitamine B_2, indicated in this country as vitamine G.[42] This vitamine is of particular interest to this country since it is capable of preventing a disease called pellagra, which has been, since 1906, a horror to the South. In the springtime, it strikes people whose winter diet has been confined too closely to corn and pork.[43] It is of importance to notice that in China where soybeans form a part of the daily ration of the people, only single cases of pellagra are reported among a 400 million population.

Experiments on pigeons fed a diet of polished rice and Berczeller's soybean flour showed the presence of vitamine B_1 (F).

Comparative studies by Professor Neumann show that the utilization of Berczeller's soybean flour by man (in the form of a 20 per cent. bread) is superior to that made from extracted bean flour, as can be seen from the table:

	Utilization of nitrogen	Utilization of carbohydrates	Utilization of fiber	Utilization of ash	Utilization of calories
Wheat-rye bread[44] containing 20 per cent. of extracted soybean flour	79.61	95.91	51.93	67.94	91.75
Wheat-rye bread[44] containing 20 per cent. of Berczeller's soybean flour	80.40	98.58	55.22	76.07	94.96

Berczeller's flour showed, according to Professor Neumann, a utilization of carbohydrates superior even to the utilization of starch in bread.

Berczeller's flour was studied by the Hungarian Food Ministry with the following conclusions drawn:

> The flour is of a pale yellow color, has a slightly sweet, agreeable, almond-like flavor and, in spite of its high percentage of oil, is but slightly fatty. . . . The soya flour prepared by the Berczeller process can supply a great part of man's demands for protein, and this, too, continually and for a long time.
>
> It can be extensively used in the preparation of bread, puddings, meats (sausages, hashes).
>
> It is of paramount interest in the question of hygienics and national economics that the

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[41] Soyolk flour has found a large market in Holland among the manufacturers of margarine. The oil, lecithin and vitamines A and D are extracted from it by means of a solvent, and this extract added to margarine, rendering it rich in vitamines and lecithin. The oil extracted from Berczeller's Soyolk flour is in quality and taste superior to refined bean oil, which is, besides, deprived of vitamines and lecithin.

[42] The growth-promoting vitamine.

[43] Special attention was given to vitamine G on the program of the meeting of the American Chemical Society at Atlanta on April 7.

[44] Rye flour 60, wheat flour 40, milling yield of 70 per cent.

extension of the soya consumption be materialized in the near future, and this can be accomplished chiefly by subsidizing the extension of soya consumption by the state.

Berczeller made a noble gesture in making a gift of his patented procedure in Hungary to the Children's Welfare Society of that country. At present, factories manufacturing Berczeller's flour are also established in Austria, Germany and England, and the introduction of Soyolk flour has met everywhere with great success.[45]

Among the various methods of using Dr. Berczeller's "Soyolk" flour, in providing human nutrition, its use in bread making is undoubtedly of the highest importance from the point of view of the hygiene of nutrition and also of social economics.

Soyolk flour has about four times as much protein as the cereals, and twice as much as the pulses. The contents of fat is fifteen to twenty times higher in soyolk flour than in wheat or rye flour. It is impossible to make bread from soya flour only,[46] but it serves to enhance the nutritive value of bread and to improve the quality of bread from a technical point of view.

Very small quantities of Soyolk flour, blended with the ordinary white flour, result in a flour mixture which possesses all the physiological characteristics of dark wholemeal flour, and bread made from it surpasses the nutritive value of bread made from whole wheat. Its flavor, taste and bloom are the same, if not superior to white bread. For 10 per cent. bran,[47] one can substitute 5 per cent. of Soyolk flour in white flour and obtain a bread with 20 to 25 per cent. more protein and 2½ per cent. more fat. Through using soya flour in breadmaking, we not only increase the protein value of this vital part of our food, but, at the same time, we substitute the more expensive daily needs of animal protein.

F. A. Richter, baking expert of the Nutrition Laboratory of Vienna, made extensive experiments in the laboratory and partly in the factories in order to examine the various processes of breadmaking by using certain percentages of Berczeller's Soyolk Flour. His statement follows:

> We took special care not to deviate from the customary flavor, taste and outside appearance of the various kinds of bread used in different countries (England, Scotland, Wales, Ireland, France, U. S. A., etc.). In none of these tried methods of making bread by adding soya flour in the above proportions could any essential change in flavor, or texture, be discovered in the bread. On the contrary, it improved the flavor of a Viennese roll and gave it a tempting appearance. We can say the same of the dark loaf of Germany, of the American cream cracker biscuit and the English wholemeal loaf.
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> In the same way we have examined white and black breads fermented with yeast and leaven, and in making rye, wheatmeal, malted bread, etc., in the different ways. Exact comparisons with and without the new soya bean flour were recorded, and every impartial visitor could observe an improvement in the quality.
>
> With such small additions of soya flour, it is not at all necessary to alter in any way the method of fermentation or of baking. As for the technology of baking, we find the following advantages by the use of the new soya flour:
>
> 1. Very small additions of soya flour enhance considerably the keeping qualities of the bread, owing to the higher quantity of protein and fat. These last qualities can also be observed in milk bread, and this is the reason why addition of fat is recommended. These observations have been testified to by a large number of bakers and by official experiments in the chemical institutes of Budapest.
>
> 2. The Berczeller soya flour has a much stronger water-absorbing capacity than ordinary flour. In proportion to the addition of new soya flour, the yield in dough and baked

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[45] In Italy, Mussolini declared to Dr. Berczeller his intention of introducing legislation to compel the use of soya flour in the manufacture of polenta, the staple maize food and bread (cit. by Hay). In the United States the building of a Soyolk factory is under way.

[46] Due to the absence of gluten.

[47] Wheat bran contains: protein 16.85 per cent.; fat 5.22 per cent. Soyolk flour contains: protein 42.52 per cent.; fat 20.24 per cent.

bread is a larger one. In caloric value the soya bread is still higher than ordinary bread.

3. We also note a saving in yeast, as the new soya flour aids fermentation, because the soya flour supplies the right quantities of the most suitable nourishment for the yeast.[48]

4. The new soya flour gives to the loaf a beautiful bloom and a pleasant tasting crumb and crust. This is due to the large amount of protein and fat in the soya flour.

5. The use of small proportions of the soya flour with the dark rye flour for the making of dark breads, which are customary in various Continental countries and in Russia, results in a bread of remarkably lighter color in the crumb and crust. The demand for whiter and, at the same time, more sustaining bread can be met in a quite inexpensive way.

Very pleasantly flavored and easily digested breads can be produced to supply the daily and necessary wants of proteins and fat for the proper nutrition of man. These breads have remarkable keeping qualities and are especially suitable for the manufacture of such kinds of bread, or similar articles, which are an integral part of the provisions for expeditions, tours, etc. In milk bread and in practically all kinds of fancy bread and rolls, where the new soya flour can substitute a substantial part of the milk, an addition of 6½ to 18 per cent. of the new soya flour is to be recommended. The nutritive value of such milk bread is superior to bread made with cow's milk. The physiological qualities and the taste are entirely substituted. Extraordinary savings are effected in the production of all kinds of small goods, such as fancy milk tea cakes, rolls, buns, scones, or anything of this nature. We not only save milk, but also yeast, malt and fat. A new economical factor enters into the business of the baker and pastrycook, both for his own benefit and the benefit of the consuming public.

Richter further extended the study of the uses of Soyolk flour for the manufacture of biscuits, pastries and confectionery goods, chocolate marzipan, custards, vermicelloes, macaronies, etc., and worked out a number of very good recipes. In Richter's opinion, Soyolk flour "acts as a perfect substitute for eggs, fat and milk, besides enhancing the nutritive value of these products." In this country, excellent doughnuts were recently manufactured with Soyolk flour without any milk or eggs.

Soya biscuits are cheaper and "outstanding because of their large content of proteins and fat. The ideal food for the feeding of children, nursing mothers, convalescence."[49] "The great advantage in the use of these articles made with the new soya flour is that it curbs the tendency in so many people to put on fat."

We must also remember that, for the young growing organism, the mixture of the soybean and wheat proteins were found two or three times more efficient than the proteins from wheat alone (Johns and Finks).

Also, a number of valuable infant foods and cow's milk substitutes can be manufactured from Soyolk flour.[50]

The Berczeller soya flour is suitable for mixing up to 50 per cent. in all kinds of sausages. It must be specially emphasized that the soya flour not only replaces the weight of the meat itself, but also absorbs a considerable amount of water (at least as much as its own weight). In the manufacture of sausages the soya flour is first mixed with an equal quantity of water, and then mixed with the mincemeat and made into sausages in the usual way. Sausages prepared in this way are extremely palatable. From a physiological point of view the introduction of soya flour into sausages can be regarded in no other way than as an improvement, since the soya flour contains only traces of purine bodies, thus preventing the development of gout.

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[48] The addition of soya flour to pressed yeast cake is being successfully tried in this country by some companies. Soya flour is also inserted in the patented yeast powders for the baking industry, shortening the ripening of the bread.

[49] Professor Moll, of the State Institute for Mothers and Children in Vienna (Austria), has obtained very satisfactory results with Soyolk flour for weak and tubercular children.

[50] Ruhräh has shown the high efficiency of soybean preparations in the treatment of summer diarrhea in children. *Amer. Jour. Med. Sci.*, cl, 502, 1915. More information in regard to the use of soybean preparation in disease can be found in the text-book on nutrition of Von Noorden and Salomon. "Handbuch der Ernährungslehre," Berlin, 1920.

In Vienna, Mrs. Hess, the head of the Federal Institute for Home Economics, undertook the study of the application of the Soyolk flour to cooking. Soon a large number of recipes were produced, the principal of which were soy-soups, meat dishes, cakes, fish salads, pancakes, etc.

In this country, the Bureau of Home Economics of the U. S. Department of Agriculture elaborated a long list of excellent recipes including common soya flour a few years before the Soyolk flour became known. These recipes are only gaining if Soyolk flour is used.[51]

For conclusion, the authoritative opinion of Professor Durig is quoted as follows:

> If soya flour can be successfully supplied in such a way that it really does not deteriorate and is as valuable for nutrition and appetizing as the samples forwarded as tests, and if, further, one succeeds in marketing the flour at a proportionately moderate price, a feat has been accomplished of incalculable significance for social economy, since it makes it possible to supply a source of protein in a degree which has never been attained by any other food. Not only in the question of feeding the people at large, but also—and that in a very special degree—with regard to feeding the public institutions, the prisons and the hospitals, prospects of great social economical importance are opened up.
>
> At the same time, one must not forget that national food questions are never to be solved from the standpoint of theoretical considerations, however correct these considerations may be, as the deciding factor is always custom and taste, and, especially, the tendency of people to seek a certain enjoyment value in their food, even when they know that they have to pay a high price for it. In any case, in spite of difficulties in carrying through an innovation such as the intróduction of soya flour into the nation's food, it is highly desirable that the question of producing some soya flour which will satisfy all the requirements of durability, full biological value, edibility and technical exploitability be energetically taken in hand and that, once and for all, a beginning be made with the extensive use of soya flour, which was also recommended by C. V. Noorden. The social political significance of this question is beyond all doubt.

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[51] For further references on this subject, see articles by Fridericia in the *Journal of Biological Chemistry*, lxii, 471, 1924; by Hill and Stuart, in the *Journal* of the American Medical Association, xciii, 985, 1929; and "The Soybean" (1923) by Piper and Morse.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

EPIDEMIC POLIOMYELITIS OR INFANTILE PARALYSIS

By Dr. WILLIAM H. PARK

DIRECTOR, BUREAU OF LABORATORIES, NEW YORK CITY DEPARTMENT OF HEALTH

IN the United States poliomyelitis occurs usually in young children and this is the reason it is commonly called infantile paralysis. In the Northern States cases usually begin to appear during June and increase during July and August. The disease diminishes in October and practically disappears in November. In the Southern States it may appear somewhat earlier and last longer. Last year outbreaks occurred in California and in the Middle West, while during the present summer we are having rather more cases in the Eastern States. The age of the children attacked varies. This year in New York City about 70 per cent. of the cases have occurred in children under five. There have been as yet no cases in children over 15.

The Nature of the Virus—We have not as yet been able to cultivate it on culture media in the same way as we do diphtheria bacilli or scarlet fever streptococci. We know, however, that the poliomyelitis microbes are much smaller than these for they pass through the pores of porcelain filters. They are invisible to us even with the greatest magnification possible.

For a long time it was thought that no animal was susceptible to the disease, but in 1909 the actual transmission of the virus of infantile paralysis in monkeys was announced by Landsteiner and Popper. Very shortly after their work was reported, Flexner and Lewis confirmed their work and transmitted the disease from monkey to monkey. The virus was found to be fairly resistant and to live for a considerable length of time outside of the human body. At present then we know that the virus is filterable and that in a developed case it is located in the gray matter of the spinal cord and to a lesser degree in the gray matter of the brain. When the spinal cord of a fatal case is placed in pure glycerin the virus lives in it for long periods of time. As it takes a considerable amount of virus to infect a monkey, bacteriologists have had great difficulty in studying the location of the virus before it invades the central nervous system and there multiplies greatly. Flexner found the virus existing in the throat secretions of a convalescent case. Swedish investigators believe that they proved the virus to be present in the pharynx and intestines of a number of healthy persons who were in contact with cases as well as in the actual acute and convalescent cases. We have other evidence that makes us believe that the germs of infantile paralysis are very widely spread and that only in a small percentage of the people infected does the virus penetrate to the blood and into the spinal marrow. This information has come to us in a peculiar way. It was discovered by Flexner that the serum of monkeys which had recovered from infantile paralysis would give protection to other monkeys as is shown by the fact that they resisted the inoculation of the virus. The next step was to find that human beings who had recovered from the disease also possessed a considerable amount of antibodies. Doctors Zingher and Neal from my laboratory used this convalescent serum extensively in New York in the epidemic of 1916. To Dr. Zingher it seemed to give striking effects in the cases when it was given before paralysis had developed. The paralysis usually not appearing in such cases. Dr. Neal was less certain as to the value of the serum.

Lately Dr. Aycock working with Dr. Rosenau and other members of the Massachusetts Infantile Paralysis Commission and the International Committee For The Study of Infantile Paralysis, whose work has been financed by Mr. Jeremiah Milbank, has used it very extensively in the metropolitan area about Boston, and believes with Dr. Zingher that it gives very striking effects. Almost everyone doubts the value of the antiserum if it is given after paralysis has developed. Not only Dr. Aycock in Boston but Dr. Weyer in my laboratory, discovered that a large proportion of the adults and older children had this antibody. This discovery indicated that the virus was widespread for as far as we know, these specific protective substances only develop after an infection. I say infection, not a definite disease. For instance, we know that in an institution in which diphtheria has developed, that besides the few cases which had developed diphtheria, there were a great many others who became immune as shown by the Schick test. If cultures are made from time to time during such an outbreak from the throats of these children, many show diphtheria bacilli. That is they were infected but the infection had not gone far enough to produce actual clinical disease. Again we know that many persons have the germs of pneumonia in their throats. Some of these are healthy, others have a tonsilitis or a rhinitis or occasionally a pneumonia. The same we believe to be true for infantile paralysis. The virus probably spreads to many persons creating in some almost no disturbance whatever, in others a little irritation of the mucous membranes. In only a small percentage of these persons does infection pass to the spinal cord and to the special nerve cells which influence muscular action. These are the only ones which develop paralysis. We believe it is for this reason that older persons become immune and the disease is so liable to be largely confined to young children. Because infantile paralysis is more or less endemic in this country, we believe the germs in other than epidemic times have less virulence, so that only a very occasional child develops the disease while the majority of persons become immune.

Can we do anything to stop the spread of the disease? Something but not very much. There are certain things that we know. The infection is spread by the infected secretions of human beings; the nasal secretions, the throat secretions, the intestinal discharges. This material when expelled from the human body remains alive for some days or weeks. In two instances the virus was transferred to a few children in raw milk. If it comes in contact with the mucous membranes of very susceptible children, some light infections and some severe ones will probably develop in a fair proportion of the cases. We try therefore to limit as far as possible, the contact of those who may be infected with those who are not infected. Therefore, we treat any case of infantile paralysis in the same way as we would a case of diphtheria. The secretions from the eyes, the nose, the mouth and the intestinal discharges are immediately disinfected. The one who nurses the child abstains as far as possible from mingling with healthy children. We have the valuable experience that children in the institutions which are carefully isolated during an outbreak of infantile paralysis rarely become infected, while those admitting visitors freely from regions where the disease is prevalent, are apt to develop it.

The Question of Summer Camps—While we are not sure that it is necessary we think it wise to limit or stop the visiting of children by their parents and friends when in camps. These visitors may be admitted to the camps if they are prevented from actually coming in contact with the children.

General Treatment of the Sick—It is known that children suffering from infantile paralysis have a better chance for final recovery if they are kept at rest when first attacked. This causes us to prevent, as far as possible, the moving of discovered cases in a camp, by railroad or by other means for long distances. That is, a child in a camp should be removed to a neighboring hospital and not to a distant city from where the child came.

What Medical Treatment is Available—As already stated we believe before paralysis develops that an intraspinal and an intramuscular injection of the serum from a convalescent case of infantile paralysis or of horse antiserum prepared from an immunized horse tends to abort the disease. We are not absolutely sure of this but we have good grounds for it. We know that an injection of serum in a monkey would protect the monkey from the development of the disease if it is later infected.

Preventive Treatment—Occasionally a second case develops in a family. We believe therefore that it is advisable to inject the children in a family where a case has just developed. When paralysis has developed we know of nothing that influences the development of the disease.

Bacteriologists working under the International Committee for the Study of Infantile Paralysis have been trying to find some curative drug remedies and have made some progress but none sufficiently definite to be employed in routine practice. It seemed that some severe cases might get well if they could be prevented from dying of suffocation. An apparatus has been developed, called the "Drinker" apparatus, in which a child can be placed and artificial respiration kept up without disturbing the child in the least. The original purpose of this apparatus was to help those who were unable to draw air into the lungs because they were paralyzed. Some lives can be saved by the Drinker apparatus but many of the cases die in spite of it from the effect of the general poisoning. The children really enjoy it.

During the first few weeks of the disease, rest is the best remedy. Later under the guidance of the physician, electrical and careful massage treatment may be given and of course various forms of apparatus applied to relieve the muscles which have suffered degenerative changes.

Infantile paralysis almost never affects the intelligence. The injury done is confined to the nerve cells and the muscle fibres supplied by them. Usually a small or a larger group of muscles is wholly or partially affected. When the convalescence is established we try to do what we can to strengthen the muscle fibres left intact in a muscle or if this is impossible we try to accustom other muscles to take over to some extent the function of those injured. It was discovered that those who have suffered from muscular atrophy because of paralysis can be benefited by exercising while in the water. Almost everyone in the United States knows that Franklin D. Roosevelt, the Governor of New York, suffered in the prime of his manhood from an attack of poliomyelitis, and that he has succeeded largely in overcoming its ill effects. Naturally being sympathetic and knowing of his own struggles to recover and · the value of exercise while in bathing, he created at Warm Springs, Ga., a sanatorium where those suffering from the disease may utilize the warm spring water to bathe in and under expert instruction learn to develop muscles which before they had believed to be useless. Of course only a certain amount of improvement is possible in bad cases.

Public Measures—In many cities one or more trained physicians have been appointed to go to children who are thought to be developing infantile paralysis and there to look for some or all of the following symptoms, headache, drowsiness, vomiting, diarrhea, fever, pain and stiffness in the back of the neck and spine, general hypesthesia and irritability. If a sufficient number of these symptoms are present, a spinal puncture is made and some spinal fluid removed. This is sent to the laboratory and if changes in the spinal fluid suggestive of this disease are noted and no paralysis has appeared, an injection of human convalescent or of refined antipoliomyelitis horse serum is given. Careful statistics are being compiled in order that we may know whether the treatment does good on the first day, the second day or the third day of these symptoms. As I have already stated, we know that after the development of paralysis no benefit can be expected from the serum. The disease is so striking in its ill effects that we are more alarmed than the number of cases usually makes necessary. However, the disease is so tragic that we cannot blame parents for worrying.

THE RATIONALE OF WEIGHT REDUCTION

By Dr. FRANCIS G. BENEDICT

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THE weight reduction wave that threatened to reduce all our young women to "bean-pole" outlines a year or so ago has happily in part receded, yet even to-day the interest in weight reduction is so great that the lecturer on physiology, medicine or nutrition has but to introduce the words, "weight reduction" at any part of his discourse to change a quiet, sleepy group into an eager, agitated, expectant band of zealots, all on edge to secure any last-minute advice on the methods of losing flesh. To paraphrase a well-known text we may say, "Some people are born fat, some achieve fatness, and some have fatness thrust upon them." At the outset it is well for the body to be well nourished but not too fat. Babies are usually well nourished. One seldom hears of any effort to make babies thin, although after they begin to be fed artificially there may be over-feeding with an over-fat baby. In the period of youth and adolescence there is usually, especially with boys, such a tremendous amount of surplus energy and muscular activity that there is ordinarily no problem of weight reduction. With girls, too, in the grammar and high-school age little difficulty arises. One season I had occasion to wait at the front door of a large high school for girls, containing 700 pupils. Not five of those pouring out of the doors could have been charged up as being decidedly too fat.

But now, as to those that achieve fatness. The girl who gives up husky or tomboy activities for mid-Victorian repose and gentility begins to have trouble. She loves sweets; she loves delicacies and goodies just as before, but the exuberant activity of the early teens has by convention been repressed. The love for sweets has not been repressed and in goes the food and there is not the former outlet for the energy. Our patient now begins to acquire fatness and the fight begins. Frankly, until 35 years of age the question of overweight is a matter chiefly of fashion, for a little extra plumpness is from the standpoint of health a real asset in the first three decades of life, since apparently it aids materially in helping to ward off the dread disease, tuberculosis. Now statistics perform some curious things, for apparently the night that you are thirty-five years of age the chances for a longer life are bettered if you are somewhat under rather than over weight, and it is between thirty-five and sixty years that the greatest danger appears and the struggle against the excess poundage is a real one. Why do people grow fat? There are, to be sure, a relatively small proportion of people with disordered glands who perhaps may be excepted, but in the vast proportion of cases there is just one answer; you eat each day a little more than you require. I repeat that you eat a little more than you require. If you eat the equivalent each day of an ounce of butter more than you need, what happens? You don't lose it; you don't burn it; it is digested, assimilated, and note this—it is deposited as fat. One extra ounce of fat means a pound in about two weeks or twenty-five pounds a year. All this from but one ounce, say three pats of butter, extra each day. Please note that I emphasize extra; that means three pats of butter above your daily needs. This goes on gradually, I might almost say insidiously, until the weight increases, the girth increases, the creases increase, and there you are.

All this is not sudden. You may not note it or you may wilfully disregard it. You may say, "Oh well, in the spring I'll get out and work it off." How will the bathroom scales help us in this matter? If you have bathroom scales use them at least once a week. If necessary write down your weight and watch the changes. Pay no attention to sudden changes either up or down. Let us see! What about sudden changes? Perhaps the most remarkable instance of a sudden change in weight that I ever knew of was that of a football player who on a warm fall afternoon lost 14 pounds during the afternoon and in this time he had played strenuous football for one hour. Now, thanks to careful analysis and studies in the physiological laboratory, it is perfectly possible to analyze this loss. Is it all body tissue? Is it fat? Is it water? What part of it is water and what part of it is fat, etc.? We know that when a football player plays to the limit of human endurance he can not produce more than say 600 or 700 calories of heat in one hour; in an extreme case 900 calories. Of course, during this time he is eating nothing, and this heat must come from material that is burned in the body and we will assume that it comes from fat. If this is all derived from fat it would require about 100 grams of fat to furnish these 900 calories. 100 grams of fat would be about 3½ ounces. As a matter of fact, he probably would not burn exclusively fat; he would burn a little carbohydrate and some protein, but we can make an extreme case and say that he might have burned all told 100 grams of fat and 50 grams of either protein or carbohydrate. This is an extreme illustration. This makes a total of 150 grams of dry body tissue burned, that is, about one third of a pound. Now dry body tissue is not peeled off the body either internally or externally as such; it is accompanied by water, and in this particular case we can see that if he burned only one third of a pound of dry body material and lost fourteen pounds there must have been thirteen and two thirds pounds of that loss due simply and solely to water. This was really a drying out of the body and it was probably all regained in the water and other liquids consumed, so that in one or two days at the outset the weight was essentially back to the original level. This furthermore illustrates the futility of trying to "work off" fat that has been deposited in the body. If it takes the terrific strain of one hour's football competition to work off or burn up one third of a pound of body tissue, what chance has the untrained, soft non-athlete to work off any material amount? Work means heat. The heat is derived from food or from body substances, so that by working one does work off body substances, but as we have seen, in very small amounts.

To come back to our ounce of fat, let us make it rather than an ounce, a pat of butter, about one third of an ounce. This one third of an ounce yields a certain number of calories when burned in the body. Now if this one third of an ounce is taken in excess of the daily needs, only a little more, to work off that particular extra pat of butter taken on that particular day you would have to do work equivalent, for example, to a walk from the bottom to the top of the Washington Monument.

The best way of all to lose fat is not to get fat. If you are fat then it is nearly hopeless to attempt to "work it off." There is only one way to lose it intelligently, and that is to limit your daily food intake slightly and burn it up slowly, but remember that if we ate each day 3 pats or one ounce of butter less than we really needed, 25 pounds of fat would disappear in the course of a year. Of course, this could be done more rapidly, although with some danger, by complete fasting. In thirty-one days of complete fasting you could lose nearly 30 pounds, but again a good deal of this loss would still be water. It is impossible to lose weight and not lose some water, for the body is really 60 per cent. of water, but what you want to lose is the fat, and that is the main objective in weight reduction.

Bathroom scales are a very good index for the long pull, for reduction covering months, and you can not reduce except in terms of months. These fat zealots wish quick results, but think, those of you who are really overweight, how long you were putting on the extra poundage, usually several months if not years, so that you must take off that fat in a proportionately moderate way.

Reduction without the continual cooperation of a good physician may really be dangerous. Rapid results can not be expected. No overnight treatment is of value. Most of the innumerable proposals for weight reduction other than by intelligent diet control are not worth serious consideration.

Every extra calorie that you eat, be it from starches, sugars, fat or protein, must be looked upon as a potential fat producer. Fats are, so to speak, twice as concentrated as starches and sugars; hence if one avoids all visible fats in the food this is helpful. Cutting out visible fats is usually not a great hardship, but of itself is of value only when there is no compensation by overeating of other equally fat-producing materials. It is useless to cut out any particular article of the diet, such as bread or potatoes, and then fill up with ice cream. Diets of salads and greens which produce a feeling of fulness are sound in principle but may easily be overdone and produce digestive disturbances.

Exercise in moderation is, of course, essential to health. Extreme exercise, especially if one is not used to it, may be easily overdone, and then there is always this point to bear in mind—a ten-mile walk to "work off fat" usually is a wonderful stimulant to an appetite all too ready to be appeased.

The use of patent preparations to produce slimness, such as various chewing gums, is nonsense. While it is true that certain glandular extracts and drugs hasten the burning up of material in the body and thus contribute in a small way, at least, to reduction, they are without exception dangerous to use without the continued advice of a competent physician. There is no royal road to slimness. Diet reduction, at times demanding a Spartan-like abstinence from especially loved foods, is the only really logical procedure. It all boils down to a careful, intelligent curtailment of food or fuel intake. It might be termed "scientific stoking."

DENTAL CARIES AS VIEWED BY THE BACTERIOLOGIST

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DENTAL caries is without doubt one of the very ancient diseases to which mankind has fallen heir. True, we know little of the disorders which attacked soft tissues in primeval animal life, including man, since these structures nearly always disintegrated without fossilization. Our records concerning early infections are thus limited in nearly all instances to evidences of destruction within hard tissues, since it is these portions which have been preserved throughout the ages by nature's methods. Tooth decay was prevalent in prehistoric man, whether from northeast Africa, Asia Minor or Peru.

Dental caries is a process characterized by disintegration of the calcareous tissues of the tooth. These lime-bearing portions of the tooth may be listed as enamel, dentine and cementum. The enamel is that intensively resistant outer layer which covers all portions of the tooth exposed above the gum in man. It is by all means the hardest and most durable structure within the body of higher animals. The cementum is the outer layer of the tooth, of that region which usually lies below the gum line. It has certain of the characteristics of bone, and has for one of its main functions the furnishing of anchorage to the fibers which hold the tooth in position within its socket. Dentine lies inside the enamel and cementum and thus is adjacent to the pulp cavity.

Even though it appears wise to consider dental caries as an infection, one must guard closely lest such a statement be construed too broadly. Bacteriologists have rapidly been approaching the conclusion that disease is much more complex than merely the growth of bacteria within certain tissues of a host. Infection denotes a change in degree of activity of at least two different factors: first, there is to be considered the invasive power of the bacterial organism, and second, resistance on the part of the tissues concerned. According to our modern concepts of growth of bacteria, their virulence, which is really their invasive power, may vary. Reasons for these changes are understood very imperfectly at the present time. The ability to resist bacterial invasion on the part of the tissues of the host constitutes another variable. Infection thus results from the overturn of a balance between a potential invader on the one hand and tissues of changing resistance upon the other. At the same time then one must not ignore the fact that, no matter how weakened in resistance tissues may be, there can be no infection without the presence of an infecting agent. Unfortunately the infecting agent usually is close by in this world of ours, but these principles underlying infection doubtless hold in the consideration of dental caries just as they do in other examples of invasion by bacterial forms.

There are many theories of the cause of caries in the teeth, and when finally we understand what this disease really is, it is likely that we shall find that the etiology of this disintegration includes a combination of factors. These possible causes may be divided into two different categories, endogenous and exogenous. Each of these subdivisions has its own enthusiastic proponents. By endogenous we mean that the cause comes from within the animal organism, while exogenous indicates the opposite, that is, that the cause is derived from without. An infectious agent thus must be included among exogenous causes. Among those factors which are inherent in the animal are to be included deficiencies in diet, and it is very certain that the teeth in their structure are most sensitive indicators of certain untoward conditions within the body. Extensive work has proved that lack of certain vitamines is reflected quickly and definitely by a certain picture of changes within tooth structure. It seems very probable, moreover, that such changes resulting from improper diet may be attended by increasing susceptibility to bacterial invasion. Doubtless the question of the relationship of diet to tooth structure is one of vast importance. There is a great demand for the element calcium within the animal body during childhood and also during pregnancy, for these are periods when bone and dental structures of the body are in process of formation. Calcium is necessary to the formation of these tissues particularly. It is not strange therefore that dental caries often appears intensively during these periods. The after effects of syphilis, especially in succeeding generations, may appear as certain malformations of the teeth when irregular and weakened dental structures may be formed, with the result that not only is the tooth less resistant to disease but its very shape makes invasion by bacteria relatively simple. These examples have been cited as factors which are endogenous in classification, and the list is by no means complete as given above.

The exogenous factors which may operate in dental caries are probably to be limited to the bacteria and the protozoa. As regards tooth destruction, the importance of the protozoa is most likely very minor, but to the bacteria a considerable amount of attention has been devoted. Among the bacteria there are two different groups which have been examined with care in so far as concerns their possible relationship to dental caries. These are a long, slender rod and a streptococcus, but it is very probable that the so-called streptococcus is only another form of the first mentioned rod. It has been recognized that this rod may appear in a number of different guises in culture and among these is the shape simulating a chain of small spheres so that it has been mistaken for a streptococcus. There is good reason for believing, therefore, that rod and streptococcus as found in the inner portions of disintegrating teeth, may upon occasion be one and the same organism.

If destruction of tooth structure is to take place as the result of the activity of certain forms of bacterial life, then these organisms must be endowed with certain qualifications. We have already noted the fact that the hardness of teeth is due to the calcium content. Organisms which can destroy tooth structure therefore must be able to break down calcium compounds. If they are able to produce acid in sufficient concentration, they may be enabled to do this. Acid usually but not always, when formed by bacteria, is derived by breaking down carbohydrate, and thus there is a definite relationship between carbohydrate and solution of calcium compounds as found in teeth.

Bacterial organisms which shall have the various requirements necessary in order to cause dissolution of dental calcareous structures have been given careful attention by a number of able investigators, including Miller, Kligler, Rodriguez and Bunting. All these have derived evidence to the end that there is a certain group of bacteria present in a carious tooth which are able to produce relatively high concentrations of acid and which also have the faculty of bringing about disintegration of this resistant structure. In addition Mummery has shown by histologic technique that there are many bacteria present *in situ* in the cavity and that certain of these have penetrated into the dentine considerably in advance of the more evident area of disintegration.

The question of the incidence of acid-producing and of acid-resisting bacteria within dental caries offers a fascinating problem, therefore, and certain experiments dealing with this subject have been carried out at the University of California. No claim is to be advanced that much of the work is original in concept of thought. Part of it is confirmatory in character; another portion of it possibly may add a few items to the sum total of human knowledge regarding the subject.

Initial experiments were carried out, and for the able assistance of Mr. E. G. Ewer, who was associated with me in this particular endeavor, thanks are extended. With the cooperation of the university infirmary dental staff a careful attempt was made to isolate organisms from dental caries which should fulfil the qualifications necessary to break down the resistant framework of teeth. The work was done upon twenty-five different patients, nearly all of whom were university students. One cavity only from each mouth was examined. The technique utilized was as follows. The cavity in the tooth under test was first cut to its approximate size by means of the usual dental instruments. Tincture of iodine was then applied not only to the inside of the nearly prepared cavity but also to the outside of the tooth and to softer surfaces adjacent. Our previous work had proved that iodine is a most efficient germicide to sterilize the surfaces of oral tissues, and that it is effective in less than one minute for this purpose. After the iodine had been allowed to act for two or three minutes, the operation of preparing the dental cavity for filling was then continued, but now a freshly sterilized bur held with a sterile hand piece was used in order that the possibility of entrance of external contamination might be reduced to a minimum. The iodine-treated surface at the bottom of the cavity was cut away and then the hard particles which the burr subsequently cut from the underlying dental tissues and which were in turn lifted out while still sticking to the cutting instrument, were carefully transferred to medium. The medium thus inoculated was incubated at 37°. From twenty-four of the twenty-five explorations thus described we isolated rods which showed considerable variation both in morphology and in dimension. Usually they were long and slender but sometimes they appeared distinctly club shaped. Oftentimes they were granular when stained, and in a few instances they might have been mistaken for short chains of spheres on account of the distinct granulation which was revealed. Culturally, all presented difficulties when one attempted to grow them upon solid media as in Petri dishes, but one was impressed with the fact that all the twenty-four cultures derived belonged to the same general group.

The next endeavor logically should be to determine whether these organisms which had been isolated from carious processes were able to cause the deterioration of resistant dental structures. To this point attention was therefore devoted.

In preparation for these particular tests concerning the possible destruction of dental enamel and dentine by means of bacterial activity, it became advisable to determine the degree of hydrogen ion concentration necessary to bring about distintegration of dental tissue. For this purpose, therefore, a supply of human teeth was obtained. These had been extracted some time previously and then after careful cleansing had been dried. There were no carious processes evident in any of them. These were first prepared by applying three or four coatings of shellac. When thoroughly dried in an incubator for a number of hours, the shellac covering was cut away from an area upon the crown approximating one eighth of an inch in diameter, in order to expose the tooth structure at that point. A series of solutions of hydrochloric acid of different hydrogen ion concentrations varying between pH 3.0 and 5.0 was set up. Into these solutions the teeth were inserted and then maintained at a consant temperature of 37° C. over the period of the experiment, which was twenty-three days. We replaced the acid solutions every two or three days in order to maintain a constant degree of acidity. The area exposed to the activity of the acid was limited as outlined above for a two-fold purpose. First, it was desired to obtain a single area upon the tooth which alone had been acted upon by the acid so that any final effects might be the more evident by contrast with the remainder of the tooth which had not been in contact with the acid. In the second place, neutralization of the acid by the calcareous material of the tooth would be much less if only a small area of the tooth were exposed to the acid and therefore likelihood of maintaining a constant concentration of the acid solutions throughout the period of experiment would be increased. To obviate this second possible difficulty the solutions were changed frequently as an added precaution.

At the close of this experiment, the teeth thus treated were removed from the several solutions, washed and the shellac removed by means of alcohol. Examination then disclosed the fact that evident dissolution of the tooth structure had followed exposure to a solution the acidity of which was pH 4.0 or greater. In other words, a hydrogen ion concentration of 3.0 to 4.0 was attended by destruction of the tooth, but if the potential were between 4.0 and 5.0, then little or no effects could be observed.

It thus becomes evident that if destruction of dental enamel and dentine is to be brought about, a certain concentration of hydrogen ion must be present.

Our next step in preparation for observing the effect of these cultures upon tooth structures was to determine the end point of concentration of acidity produced by these cultures in a certain standard medium, in relationship to the final degree of acidity in similar medium produced by strains of *B. acidophilus* derived from the intestine. There has been much discussion during recent years regarding this special point. Certain authors have maintained that these organisms from teeth, in their ability to produce acidity by breaking down carbohydrate, vary in no respect from those similar cultures isolated from intestinal contents. Others, on the contrary, hold that dental strains are more active than those from the lower digestive tract, and that thus they can and do produce a higher degree of acidity than the latter. In the course of our work it became necessary for us to give attention to this matter, and in preparation for this test six strains of *B. acidophilus* stated to have been isolated from intestinal material, were obtained from Dr. N. Kopeloff, of New York City.

As a medium for this experiment dealing with the relative concentration produced by these bacterial strains, we selected milk, since their growth in this is luxuriant. The same batch of medium was used for all cultures included. The various containers of the medium, after inoculation with the organisms, were incubated at 37°, and from time to time tests for purity were made both by stain and by streaking out on glucose agar. At the end of ten days, all these flasks of cultures were tested electrometrically to determine the final pH of the solutions. All the twenty-four strains derived from dental caries gave readings lying between pH 3.3 and 3.7, while the six strains of intestinal origin yielded results between pH 3.7 and 4.3. Thus it was shown that dental strains of *B. acidophilus* are more intense producers of acid than those from the intestine. It becomes evident therefore that destruction of a tooth should be produced more readily by the first group than by the second.

In preparation for the actual test concerning the possible effect of *B. acidophilus* upon teeth, the technique followed when surveying the effect of acids upon teeth was utilized. There were certain additional precautions which, however, must be observed. The teeth under test must remain suspended in the culture and one must be able to transfer the tooth from tube to tube of culture medium. Some simple method of manipulation of the tooth thus must be provided. With this end in view we attached a fine thread to the apex of the tooth by means of shellac. The thread then in turn could be held between cotton plug and the lip of the culture tube so that now the dental tissue was suspended. Covering by shellac and subsequent careful abrasion of a small area upon the crown was carried out as outlined in our previous discussion. The teeth were then sterilized by steaming intermittently in the Arnold.

We then prepared cultures in milk of the thirty strains of organisms of which twenty-four had been cultured from teeth and six from fecal material. The human teeth prepared as outlined in the previous paragraph were then suspended within these cultures and again we maintained a constant temperature of 37°. It should be remembered that in the mouth there is constant flushing on account of the flow of saliva with the result that products of bacterial metabolism are removed. True, the effect is but momentary, since organisms are constantly flourishing and thus these products are rapidly replaced. We do know, however that there is a decided self-inhibition with consequent death curve if these products are allowed to accumulate in great degree. We obviated this difficulty in small part by transferring the teeth now under test to fresh and rapidly growing young cultures of the organisms once weekly. By so doing, younger and more rapidly proliferating bacterial organisms were utilized and a maximum effect upon the teeth was to be expected. Inasmuch as the teeth were suspended upon threads, transfer was a simple matter and possibility of contamination was reduced to the minimum. The experiment was prolonged for a period of six weeks, and at its conclusion the teeth were washed in water, dried and then examined to determine the nature of effects produced upon that surface of the tooth which had not been covered with the shellac and which therefore had been exposed to chemical action on the part of the bacteria.

Disintegration of the dental structures had been produced by each of the twenty-four cultures derived from dental caries, while on the other hand only one of the six fecal cultures of *B. acidophilus* had produced any visible effect whatever. Moreover, this artificial caries which had been induced was of additional interest because of the fact that not only had cavity formation progressed at the exposed area, but in addition, the chalky, white appearance which attends the advance of caries clinically was evident. Therefore, it was demonstrated that these organisms removed from teeth are able to bring about distintegration of tooth structures although the probability of like action on the part of fecal derived forms is vastly less. In this connection it will be recalled that the final pH of cultures between these two origins of strains also differed.

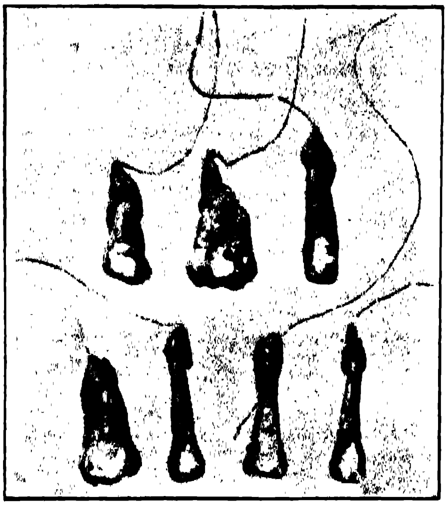
There are certain points of interest regarding the metabolism of these bacterial forms which are of importance. They require carbohydrate for energy, and by the splitting of this, acid is produced. Nitrogen is essential. The question arises as to the source of food materials necessary for the life activities of these organisms. Attention is due the white material which readily accumulates in the interstices between teeth and upon their uneven or rough surfaces. It has been determined that this materies alba yields carbohydrate, nitrogen compounds and inorganic complexes necessary for growth of *B. acidophilus,* and that therefore there is a certain relationship between the presence of this white material which is in part incompletely digested food material and the growth of *B. acidophilus.* This particular point of itself weakens the arguments of those who reason that these bacteria can have no causative relationship to caries and who base their reasoning upon the statement that caries does not progress to any marked extent after death of the host. They say that the necessary organisms are present in the mouth of the dead host and yet the advance of caries now is arrested. The real explanation lies in the fact that no longer is there an intake of starch from which later simpler sugars are inverted. These and other food materials necessary to growth of the bacteria are lacking. Of necessity the progress of caries must be arrested after death of the host. The essential metabolism of the bacteria constitutes a limiting factor to their proliferation.

One may argue that bacteria are not the cause of caries since at times cavities appear upon surfaces of the tooth where seemingly it is smooth and thus in a location where bacteria can not accumulate, since these particular forms are unable to stick to a smooth surface. These arguments are answered in part by the possible presence of malformations upon the tooth and again by plaque formation due to precipitated mucin in an acid medium. In addition to these, however, there is another factor which lies within the field of the bacteriologist, for inside of the human mouth is to be found still another group of bacteria which may be of surpassing importance to the initiation of caries. These are long chains of rods which are cultured only with great difficulty over a sequence of culture-generations, as has been demonstrated by certain European workers. The members of this group, of which the organism Leptothrix is an example, tend to attach themselves tenaciously to surfaces and thus offer a site for growth to accompanying forms. On account of the anchorage afforded the Leptothrix and allied forms, cavities ultimately may be produced by organisms because of the opportunities offered by proliferation of a form entirely foreign to the final result. In all probability this is an example of commensal activity of bacteria within the human mouth.

While considering the general question of the growth of these forms of *B. acidophilus* in and upon teeth it is wise to direct our attention to the fact that dental caries means more than merely the solution of calcareous compounds within the tooth. In cooperation with Miss Williams in our department at Berkeley, it has been demonstrated that there is an organic framework in enamel. That there is such a structure in dentine has long been recognized. This dental enamel matrix, however, is extremely tenuous and difficult to reveal. Very fine determinations made by Evans years ago indicated that in human enamel there is a possibility of only 1 to 2 per cent. of organic matter. Recently the work of Bodecker and Gies in New York and of the author upon the Pacific Coast has proved not only that there is a protein framework within dental enamel, but that it is definitely organized and with fairly exact morphology. In this particular field our work was done with the teeth of the guinea-pig, and it was demonstrated that the matrix found within the enamel consists of a honeycomb of tubes which are 1.5 to 2.5 microns in diameter. Within these the enamel rods are laid down. Additional details may be obtained by reference to the published work of the author. Dental caries, therefore, in addition to the destruction of calcium compounds includes solution of organic materials.

In cooperation with Miss Rose, of our university, lengthy experiments have been carried out in an endeavor to tabulate cultural and serological characteristics of the series of *B. acidophilus* cultures derived from dental caries. It must be admitted that the usual sugar reactions used by bacteriologists to classify organisms here are inadequate. We were unable to determine any constant set of sugar and other cultural changes which may characterize this group, and in this we note the same picture of events as has been recognized by other workers in this special field. Many of the sugar reactions are inconstant even with the same organism following repeated trials. Some certain carbohydrates may be acidified at one time but not at another even though all known precautions be taken.

We met similar difficulties in endeavoring to observe agglutination reactions of these forms, for we desired to learn whether they may fall within certain groups as indicated by agglutination technique. Two rabbits were immunized by repeated intravenous injection of each of the twenty-four strains of dental bacterial organisms, and these injections produced no unfavorable reactions upon the animals. The antigen was prepared by growing the bacteria in glucose broth which then was centrifugalized and the sediment used for injection purposes. From time to time the titer of the several animals was tested by trial bleeding from the ear vein, and when finally it appeared that as high a titer as possible had been reached, the animal was sacrificed by exsanguination. The resulting sera were stored at ice-box temperature until further use. For our final work in attempting to classify these forms in agglutination types, we thus had available two sera for each strain, since two different animals had been utilized for each. A few of our strains gave spontaneous agglutination, and this we did not succeed in obviating either by reducing the concentration of electrolyte, which in this instance was sodium chloride, or by use of a compound such as sodium oleate to alter surface tension. These two or three strains were of course agglutinated by their specific sera, but they flocculated likewise in all other liquids utilized and thus with these the test was valueless. Each of the remaining twenty-one strains agglutinated with each one of the two of its specific sera, but there was no constancy of reaction with the antisera prepared against the remaining members of the group. On many occasions cross agglutination appeared, it is true, when one serum was used with the entire group of cultures, but when the duplicate serum prepared for that particular strain likewise was placed against the whole series of antigens, there was no guarantee that the second serum would operate in a manner identical to that of the first. The sera therefore against strains which did not show spontaneous agglutination were always homologous, but they proved to be very irregular in heterologous relationships. Thus our efforts to prove type relationships within this group of *B. acidophilus* isolated from dental caries were fruit-



HUMAN TEETH
DISINTEGRATED LOCALLY BY *B. acidophilus* ISOLATED FROM DENTAL CARIES.

less. We are of the opinion that these forms do not fall into type relationships in the accepted technical sense of the term.

The question of varying degrees of resistance to the infection of caries is a most baffling one. That this resistance to infection really does exist in many instances is certain. Moreover, it may vary in the same individual, since there are a number of instances on record where the advance of a carious process has stopped. The fact that in such arrested caries, strains of *B. acidophilus* may be isolated from the lesion which now no longer is progressive, has in turn been seized upon by those who oppose the idea that dental cavities result from bacterial activity. It should be recognized, however, that this objection to a possible etiological factor present in an inhibited site is not entirely valid inasmuch as similar conditions of arrest in the face of the presence of an infectious agent are found rather frequently in other portions of the body. It is very likely that in these instances and in cases of others who appear to be constantly resistant to the onset of dental caries there are factors at present unrecognized which operate towards prevention. It is conceivable that these may be chemical or physical; possibly they may even be anatomical in character. It is likely that the future will reveal some relationship now unknown between susceptibility to dental caries and diet.

The question of resistance to dental caries all too frequently is confused with immunity. By immunity one means an opposing factor either cellular or humoral or both which has resulted in the formation of antibodies through circulatory contact with an antigen. Such immunity presupposes a tissue and circulatory articulation which probably does not exist within dentine and which is still less likely possible in enamel. It is true that channels of intercommunication through the junction between dentine and enamel have been demonstrated

B. ACIDOPHILUS
ISOLATED FROM CARIOUS TOOTH. PURE CULTURE.

repeatedly by workers. Indeed in our collection of materials we have slides showing these. It is true also that the researches of Van Beust and others indicate channels of a sort within enamel itself. Nevertheless, the lumena of these passages is so small that one can not conceive that a cell of any sort may pass through them. Circulation if it exists at all can include at most merely the slow passage of an extremely small amount of fluid entirely without cell contact. Even this degree is by no means an assured fact. In light of these considerations, it seems very likely that there can be no immunity in the usually defined sense of this term of a host towards dental caries. Resistance has been demonstrated, but that is not immunity.

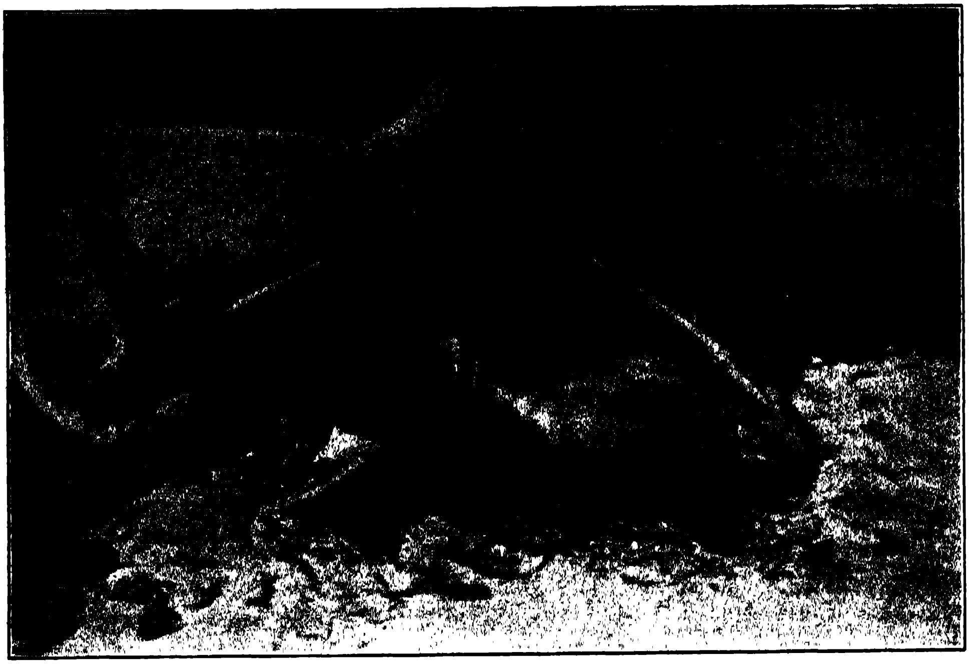
In this discussion, then, it has been our endeavor to show that it is probable that there is a bacterial etiological factor in dental caries. No claim is entered that this is the sole factor, but we have attempted to prove that organisms which may be cultivated nearly always from a carious lesion may in turn induce the result. A certain degree of hydrogen ion concentration is necessary in order to break down human teeth by solution. These organisms produce this appropriate degree of hydrogen potential. Likewise they can dissolve the calcareous structure of dead teeth. The metabolism of these forms is in large degree dependent upon decomposing food materials found about the teeth. In addition dental caries includes more than the mere solution of dental calcareous material since an organic matrix in enamel is liquefied also. These organisms are not identical in all respects to other groups found within the intestine since the final degree of acidity produced is not the same in the two series. A commensal relationship between two different groups of bacteria appears to function within the mouth since one series may furnish anchorage for another.

These caries-inducing bacteria do not show constant cultural reactions particularly as regards their effects when in contact with certain carbohydrates. Neither do they show immunological types. The probabilities of true immunity in dental caries seem to be remote.

A SHARK ENCIRCLED WITH A RUBBER AUTOMOBILE TIRE

By Dr. E. W. GUDGER
AMERICAN MUSEUM OF NATURAL HISTORY
and Dr. W. H. HOFFMANN
LABORATORIO FINLAY, HABANA, CUBA

THE senior author has already published two articles (*American Museum Novitates*, 1928, No. 310; and *Annals and Magazine of Natural History*, 1929, ser. 10, vol. 4) describing mackerel and other fishes with rubber bands encircling and even partly imbedded in their bodies, and has on hand six other specimens showing this phenomenon in more exaggerated form. What then could be more logical than for the junior author to send him a clipping from the rotogravure section of the *Diario de la Marina*, of Habana, Cuba, for Sunday, September 21 last, containing a reproduction of the picture which is included in this article. Above the picture was a short caption and below an interesting account of the phenomenon. A translation follows herewith.



—Photograph by courtesy of *Diario de la Marina*, Habana.

THE SHARK, ENCIRCLED BY A RUBBER AUTOMOBILE TIRE, ON THE SHORE OF COJIMAR BAY, EAST OF HABANA HARBOR.

THE LAST CONTRIBUTION OF A RUBBER TIRE

In the vicinity of the coast opposite Habana, where fishermen are navigating their small boats daily, two fishermen, when outward bound as usual, recently saw an enormous shark which was making a great disturbance at the surface of the water. It was unable to swim and apparently remained stationary as if moored by an anchor at the bottom of the sea. The fishermen, actuated by curiosity and the desire to make a good catch, decided to approach the fish. When they did so they were surprised to see that it was a shark of the "Alekrin" kind about five meters long which had been caught by a rubber tire . . . which the owner had thrown into the sea, having decided to replace it by another.

This shark, one of the most voracious of its kind, seeing the circle of the rubber tire, had thrust its head into its center and there remained trapped in the manner in which we see it in the photograph. This placed it in a position to be easily captured thanks to the rubber tire. This latter, after having for many years rendered its service to an automobile, nevertheless cheers us with a last contribution—the deliverance from one of these terrible sharks.

A letter to the director of the *Diario de la Marina* brought a copy of the photograph and a very courteous reply from Señor Gonzalo Menéndez, the managing editor, expressing his regrets that he could give us no further information than that contained in the note above set out. Inspection of the figure showed the shark in question to be a male of a non-determinable species.

Information has been hard to obtain, but the persistence of the junior author has finally produced some data. Our first efforts were to ascertain if the fish swam into the tire or if it was caught and the tire put on it by human hands. Our earliest information was that the fish when seen by the fishermen as noted above was literally "alive and kicking" but unable to move save at a snail's pace. It was in the bay of Cojimar, off a small fishing village about five miles to the east of the mouth of Habana Harbor—from which place we have recently put on record the capture of a second whale shark from Habana waters.

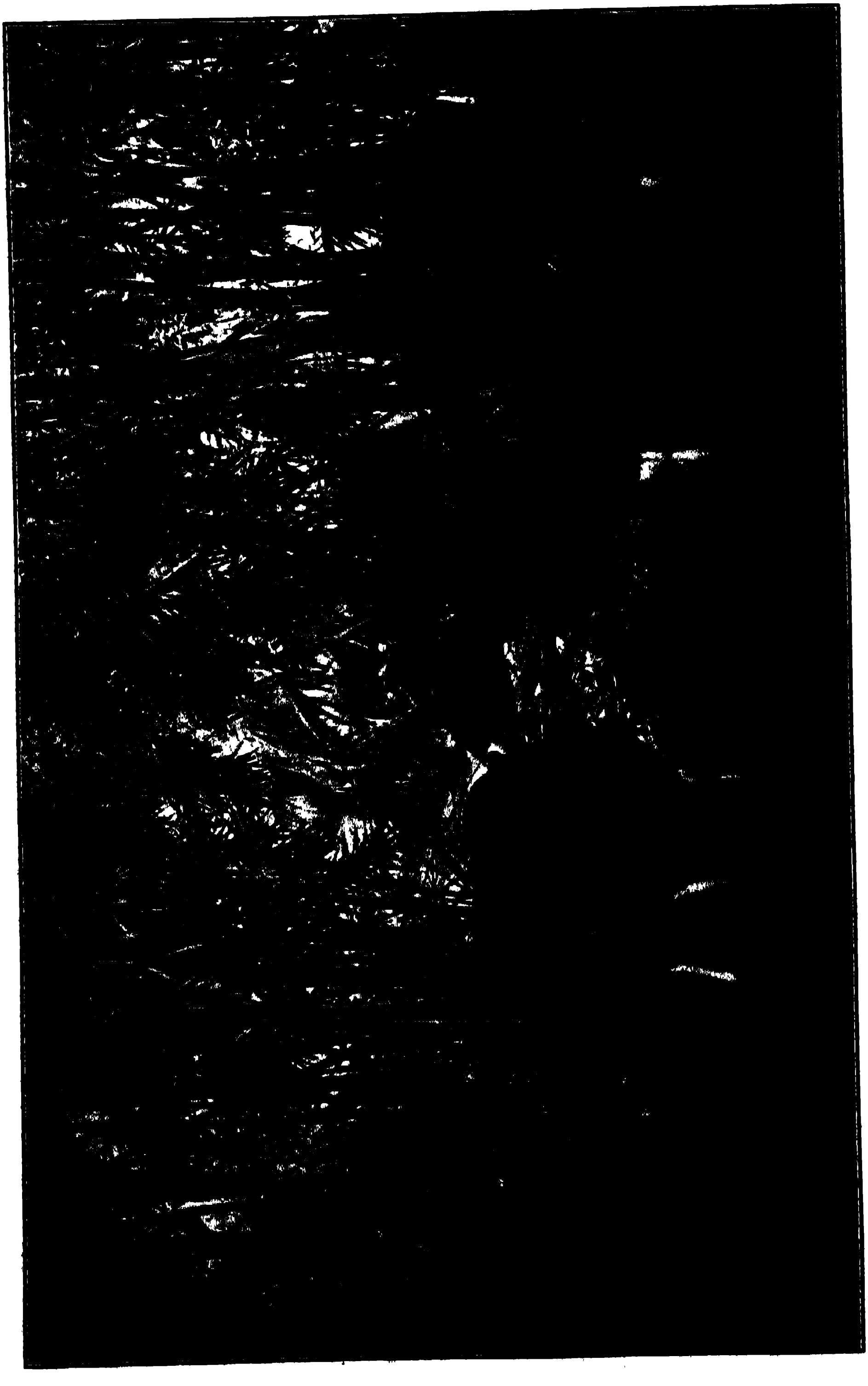
Our next information came from a gentleman who saw the fish alive but who described it as very weak, almost dead. This exhaustion was undoubtedly in part due to the efforts it had made to swim in spite of this great hindrance, and in even greater degree because it had practically been unable to catch any food since it became encumbered with this tire.

Finally Dr. Hoffmann himself made a trip to Cojimar and there found the fisherman who gave us our most reliable information about the second whale shark. He also saw and talked with the two boys who actually caught the shark. All three of them saw the fish swimming along and trying to jump out of the water in its efforts to free itself of the incumbrance. But these only drove the tire further back until it had come to encircle the body of the shark just in front of the first dorsal fin. One man said that the tire was so tight on the fish that one could see the ring it had made in the skin and flesh, and that the only way to get the tire off was to cut the shark to pieces—as was done. This, if correct, would indicate that the tire had been on the fish for some time.

The shark was actually caught by two boys who cautiously approached it as it was floundering along on the surface of Cojimar Bay. When they saw that it was practically helpless they approached nearer and getting a lasso over its head brought it to shore where they killed it after it had been photographed.

Now the final question is how did the tire come to encircle the shark as is shown in the photograph? And at once we may dismiss the idea that it was placed there by the hand of man. No sane man is going to attempt to put an automobile casing over the head of a large vigorous savage shark and to drive it back clear of the pectoral fins. We believe that the explanation is to be found in the following facts, which agree in essence with those offered by Dr. Gudger to explain how his specimens of northern fishes came to be adorned with rubber bands.

As in New York, so in Habana, garbage, street cleanings, wastes of all kinds are collected, loaded on scows or barges, and these are towed out to sea and their loads dumped overboard. Sharks are scavengers and they attend these scows to their unloading grounds to feed on garbage. When this with the worn automobile tire and other like débris was dumped overboard, our shark dashed into it to pick up what he could to ease his hunger. The open ring of the automobile tire confronted him with something edible beyond. Laying his pectoral fins close against his sides, he drove through to find himself stopped when his non-bendable dorsal fin struck the rim. Finding himself caught he became panic-stricken and pushed against obstacles to sweep this clinging thing free from his body—with the results that we have seen.



THE BANTING GROUP

THIS SPECIES OF OXEN IS PROBABLY ONE OF THE PROGENITORS OF DOMESTIC CATTLE.

THE PROGRESS OF SCIENCE

THE VERNAY-FAUNTHORPE HALL OF SOUTH ASIATIC MAMMALS

THE American Museum has opened the new hall of South Asiatic mammals dedicated to the men whose efforts had brought it into being, Arthur Stannard Vernay and the late Lieutenant-Colonel John Champion Faunthorpe. It is believed that this is the first occasion that an entire museum hall, filled with large groups of the major species of mammals especially mounted for the hall, has been opened to the public as a completed entity. That such a comprehensive collection of South Asiatic mammals could be assembled, mounted and displayed in harmony with the ideals of best modern practise in the comparatively brief span of years from 1922–30 is due to the enthusiasm and energetic support of the two Englishmen for whom the hall is named.

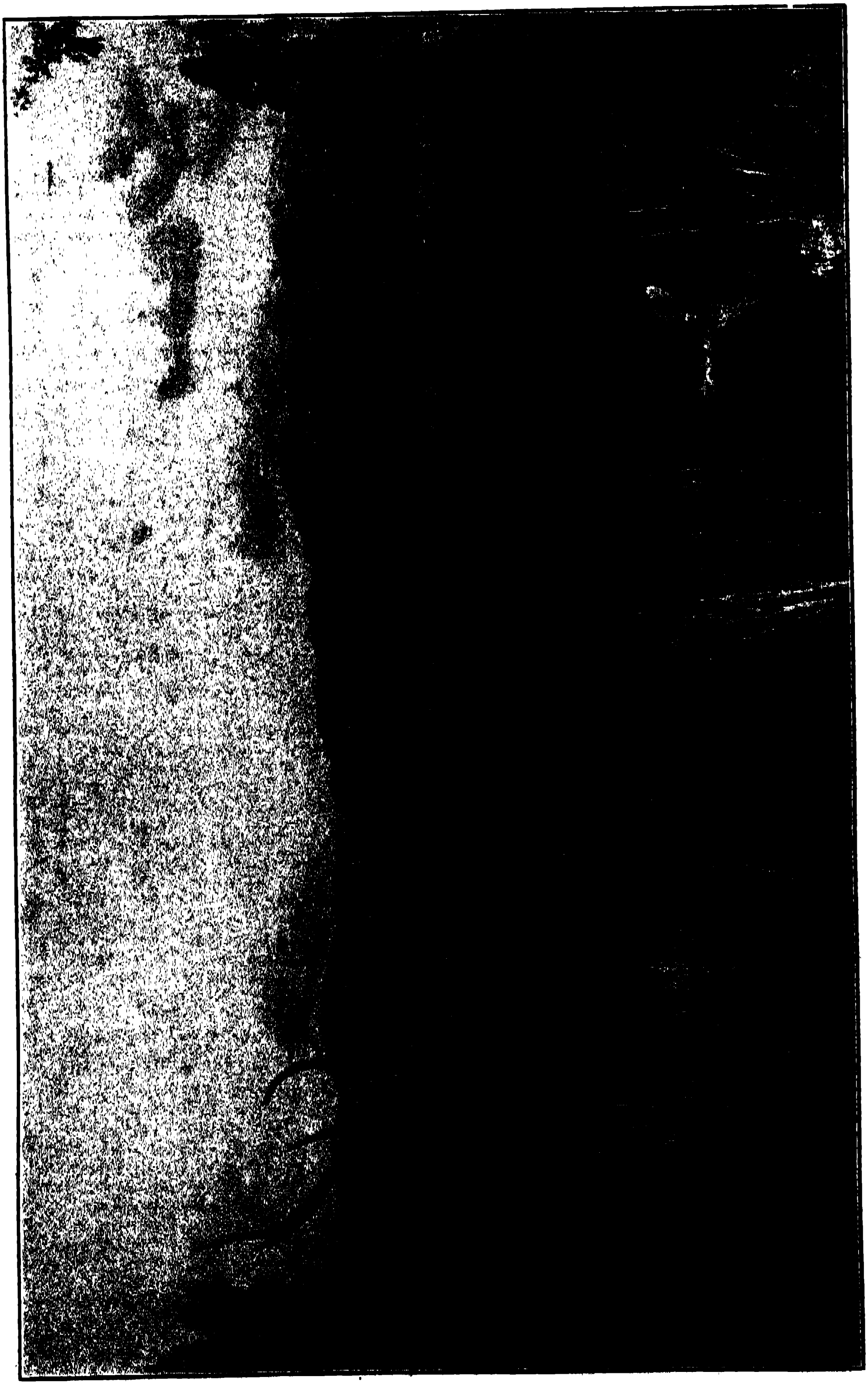
In 1918 Lieutenant-Colonel Faunthorpe, then a member of the British War Mission to the United States, visited the American Museum and at a conference with President Henry Fairfield Osborn suggested that he undertake to secure in the field some of the species of large Asiatic mammals so conspicuously absent from the museum halls. The suggestion appealed to the president of the museum, the idea was expanded when Mr. Vernay joined Colonel Faunthorpe in volunteering his services in the field and the plan for an entire hall of mammals collected by these gentlemen took concrete shape.

Messrs. Vernay and Faunthorpe were familiar with local conditions in southern Asia, they had the entrée to those entrusted with the care and preservation of large game and were altogether well equipped by experience and training for the task they had undertaken. Most important of all was the generous assumption by Mr. Vernay of all the necessary travel and field expenses and, in addition to those, some of the costs of mounting the material after it reached the museum.

The first expedition was launched late in 1922 and was followed by no less than five others before all the material needed had been secured. No efforts were spared to obtain the finest possible representation of the important mammals of southern Asia and on one of the expeditions Mr. Vernay took with him Mr. Albert S. Butler, assistant chief of the museum department of preparation, to collect accessory materials, and Mr. Clarence C. Rosenkranz to paint background studies.

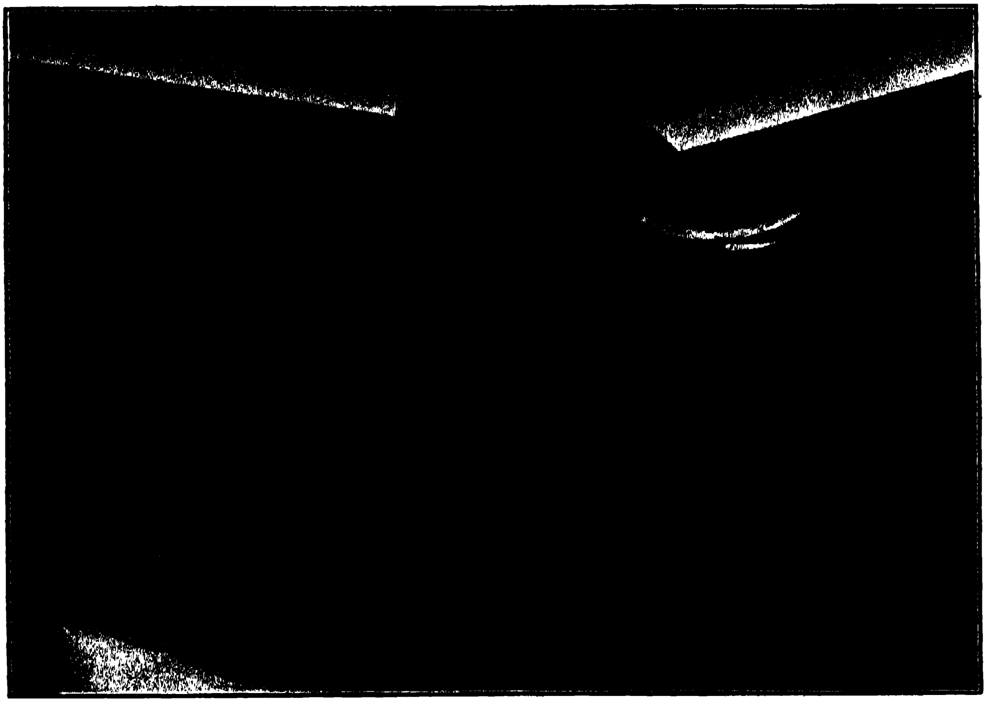
Messrs. Vernay and Faunthorpe met everywhere with the cooperation of the various Indian princes and government officials without whose sympathy the enterprise could not have achieved such success. It was a great tragedy that Colonel Faunthorpe should be stricken with pneumonia while in Lucknow, in 1929, and did not live to see the final and tangible expression of his dream of an Indian hall.

The Vernay-Faunthorpe Hall displays the outstanding species of the larger mammals of southern Asia and by means of painted backgrounds and skilfully arranged accessory material creates the illusion in the mind of the beholder that he is looking upon a transported bit of Asia. Mr. James L. Clark, assistant director in charge of preparation, has been extremely successful in creating a convincing, harmonious and artistic display of wild life. The architecture of the hall is simple, but carefully designed, with the motif of the older Indian culture worked out in teak wherever wood is used. The lighting of the groups is all from within, each group an individual problem, and there are no disturbing reflections as is the



SAMBAR AND SWAMP DEER GROUP

Represented in a marshy tract in the Tarai, along the foothills of the Himalayas.



THE INDIAN ELEPHANT GROUP

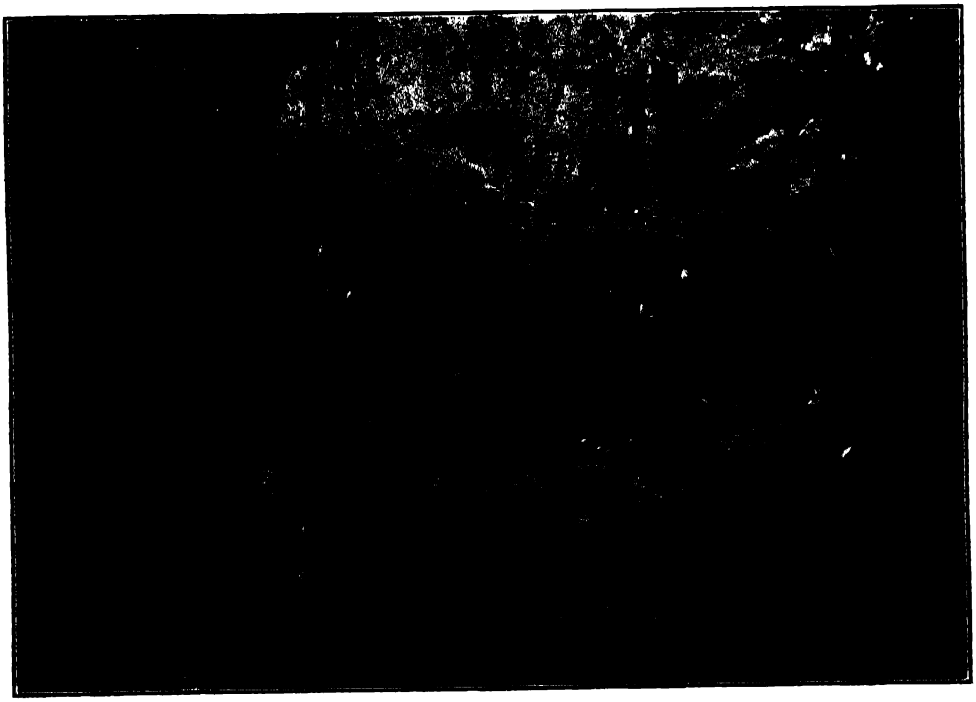
case with external lights. The exclusion of direct sunlight prevents the rapid fading of pelage. There is ample illumination where it is needed and yet the average light intensity is so low that the eye experiences a distinct relief and relaxation when the visitor enters, and "museum fatigue" is left at the threshold.

There are eight large habitat groups in the hall, displaying respectively the Indian rhinoceros, banting, Sambar and swamp deer, tiger, leopard, Sambar stag and wild dog, gaur and Indian buffalo. Smaller habitat groups present Eld's deer, Hoolock gibbon, black buck and Indian gazelle, and axis deer. Open groups down the center of the hall show a pair of Indian elephants, a pair of the very rare Indian lions, the sloth bear, and the nilgai. Lesser species from wild boar to mouse deer are contained in cases placed in lateral alcoves, where a female and young of the scarce Sumatran rhinoceros keep them company.

It is difficult in words to set forth the convincing elements of illusion so apparent upon a visit to the hall. Hunters of Indian game recognize the exact spot where the Himalayan foothills overlook the swamp deer, for example, the reason being that the background is a faithful painting of a specific locality and not just a pleasing pigment of the artistic imagination. The mammals appear to be capable of movement in the next instant, and in many similar details Mr. Clark and his staff have achieved an unqualified success.

Mr. Vernay and Colonel Faunthorpe wished to express through the donation of this matchless collection of mammals some of the great friendship and affection they felt for America, and the American public is greatly indebted to these sportsmen for this privilege of having always on display such a comprehensive assembly of the fast disappearing mammals of Southern Asia.

H. E. ANTHONY



THE LEOPARD GROUP

THE LION OF INDIA GROUP

THE NEW REFLECTOR TELESCOPE OF THE U. S. NAVAL OBSERVATORY

Many years ago I overheard a famous old admiral say to a younger officer: "Don't tell me what you are going to do. Wait till next year, and tell me what you have done." A fine working principle for sailor-men; but it doesn't suit the press, which is continually striving to get advance information of what is going to be done. And so it is in this case of our big new reflector telescope.

Frankly, I would much rather wait till the work is finished, and the results would speak for themselves than to go counter-clockwise to a habit of years, but a telegraphic request for a description of our new telescope can not be delayed a year without discourtesy. It is with extreme reluctance, however, that this task is undertaken.

Our contract calls for the construction and installation of a Ritchey-Chrétien Aplanatic 40-inch Reflecting Telescope, complete with all fittings, driving mechanisms, refinements, accessories, etc. The contract price is $76,000, and the time of delivery is to be within twenty-seven months. It is hoped that this date will be anticipated by several months.

The telescope will be mounted in a separate structure, which, in some respects, will be as wide a divergence from the usual type of observatory dome as the telescope itself is from the usual type telescope. Due to some unique features of the reflector, the size of the dome will be very much reduced with the consequent reduction in cost of the structure.

The telescope will measure not more than 10 feet overall, and the principal mirror will have an outside diameter of approximately 40¾ inches, with a clear aperture of 40 inches. Both mirrors will be made of a special grade, low-expansion glass having a coefficient of expansion only about half that at present in use. Professor Ritchey has been experimenting in the development of this glass for the past seven years in the famous St. Gobain glass works near Paris. Thanks to the liberality of that company, Professor Ritchey was permitted unlimited scope in his experiments in high-grade glass-making. As a result, he developed high-grade, low-expansion glass of a quality particularly adapted for reflector telescopes. This feat alone, if for no other, places Professor Ritchey in a premier position.

The principal mirror will be approximately 6 inches thick, and the secondary mirror will be approximately 2¾ inches thick. The latter will have a clear aperture of approximately 16 inches. The distance between mirrors will be approximately 96 inches and the equivalent focal length 271 inches.

The reflector will be mounted upon a large rigid iron casting, which in turn will be mounted upon a massive concrete pier. The bearings of polar axis will be supported on columns in the usual approved way. The entire weight of the telescope and all its auxiliaries will be taken up by a thrust bearing of Professor Ritchey's own design. This thrust bearing absorbs the load so neatly that the driving mechanism can turn the reflector with the greatest conceivable precision and smoothness.

The mounting of the telescope will permit observations clear to the celestial pole, and will be free from those annoying inconveniences which are sometimes present in equatorial mountings.

Professor Ritchey and Professor Chrétien have been perfecting the numerous accessories and developing the many refinements—some can truly be called super-refinements—since 1910, and have gradually brought their telescope to a very high state of perfection.

It is assumed that all the readers of The Scientific Monthly are more or less familiar with the fundamental principles of this super-telescope; a really remarkable telescope, embodying as it does so many minute refinements and practical solutions of difficult problems.

Professor Chrétien proved by mathematical investigation that in order to obtain the finest possible results it would be necessary to restrict the investigation to a single equivalent focal ratio for a given telescope. He accomplished that by using a single pair of mirrors always in combination, a large concave and a small convex. The curves of these two mirrors differed slightly from the paraboloid and the hyperboloid, respectively, of the Cassegrainian system.

Professors Ritchey and Chrétien developed their formula for the curvature of their mirrors, which renders the combination so far superior to all others previously made, and as a result of which the Ritchey-Chrétien reflector is capable of such astounding results.

Having settled that very important question, they devoted their energies to the solving of the many problems, hoping to overcome the well-known difficulties in the various large reflectors.

Their success far exceeded their fondest expectations.

They have developed a very short, rigid, modified Cassegrainian type reflector with entirely new curves in their mirrors, giving them an equivalent focal length which permits the photography of very faint nebulae.

All questions of construction have received the closest attention and have been solved in very practical ways. No detail was too small to be thoroughly analyzed and solved, sometimes in a very ingenious manner.

The result is a reflector of extremely short overall length, stiff and very rigid, free from flexures, capable of very rapid and skilful work, and equipped with every conceivable refinement and convenience for the operator. As an example of the detailed study of each factor influencing the perfection of the result, Professor Ritchey has even gone to the refinement of manufacturing his own photographic plates. These plates will be round and approximately 7½ inches in diameter. They will be ground and polished by Professor Ritchey personally and their surface will be true to within one fifty thousandth of an inch. Professor Ritchey was not satisfied with the plates ordinarily used for astronomical photographs, nor was he satisfied with the emulsion. He therefore delved into the technique of photographic emulsions and developed one whose granulation is twelve times finer than that used at present. This special emulsion of Professor Ritchey's will be only 10 per cent. as thick as the usual emulsion on photographic plates. This will overcome the present comparatively uneven surface of plates used for celestial photography. By means of these special plates the rays from the celestial bodies will be brought to an absolutely accurate focus over the entire plate, a feat impossible with the present equipment in common use.

Unfortunately, many of the solutions of the various problems represent in themselves what might be called "trade secrets." And as Professors Ritchey and Chrétien have not protected themselves by patenting these numerous valuable accessories and developments, it would be highly unethical for me to describe them in this article. Suffice it to say that they have developed some of the neatest and most ingenious refinements and accessories that can be imagined.

Professor Ritchey and Professor Chrétien claim for their reflector the following advantages: (1) Adaptability for the broadest general usefulness in astronomical photography; (2) arrangement of mirrors to permit the most convenient form of equatorial telescope; (3) focus of optical combinations in readily accessible position near the center of motion of the instrument; (4) position of this focus never far above the floor level of the dome; (5) freedom from flexures of the tube; (6) reduction of the effects of expansion and contraction of the tube at least one hundred times; (7) permanence of alignment and the separation of the two mirrors; (8) ability to focus to one ten thousandth of an inch, in marked contrast to the present methods, which permit accurate focusing to only about one one-hundredth of an inch.

In addition to the foregoing, and as a result of some of those characteristics, Professor Ritchey called my attention to the large field of extremely small, round, concentrated images quite in contrast to the many others not possessing the same degree of definition or accuracy, particularly away from the center of the plate. The smallness and the clearness of images, even out to the periphery of the photographs, is very remarkable. A greatly increased accuracy of measurements of astronomical photographs naturally results.

In discussing the capabilities of the new reflector one day, Professor Ritchey remarked: "We shall make photographs with it which correspond to 90 per cent. of the full theoretical photographic resolving power due to the aperture, instead of the 10 per cent. or less represented by the best celestial photographs at present. And we shall do this where, of all places, it should be done: at our National Observatory in Washington."

The aim of Professor Ritchey was to develop a type of reflector of universal usefulness, one of great optical power and refinement but with great economy and convenience of all mechanical features.

Professors Ritchey and Chrétien will receive the thanks of the scientific world when the results of their years of painstaking investigation and development can be made public.

Frederick Hellweg

MARTINUS WILLEM BEIJERINCK[1]

1851–1931

Far from the great city and from his laboratory, there passed away on January 1, in a little town in Holland, one of the greatest scientists of the age, Professor Martinus Willem Beijerinck. Born at a time when Pasteur fought his great battle for the recognition of microorganisms as the active agents in disease, Beijerinck has materially contributed to our understanding of the rôle of microorganisms in natural processes and has indicated numerous applications of the activities of these microscopic forms of life to agriculture and industry.

When a youth, he used to wander over the sand dunes of Holland, in the neighborhood of Haarlem, and observe the life of these dunes. At the age of 16, he competed for a botanical prize, which consisted in making a collection of 150 different plants, and he won this prize. From this humble beginning, he proceeded to make some of the greatest contributions to our knowledge of microbes, including fungi, yeast, bacteria, algae and amoebae, as well as filterable viruses, and established their rôle in the growth of plants (pathogenic and beneficial), in soil processes and in industrial applications.

A friend of van't Hoff and of Hugo de Vries, he combined chemistry and botany to establish the rôle of microscopic forms of life as chemical reagents and thus advance further and enlarge greatly upon the ideas of Pasteur in the same field. Although his investigations did not lead to such spectacular results as those of Pasteur, those that have had an opportunity to familiarize themselves

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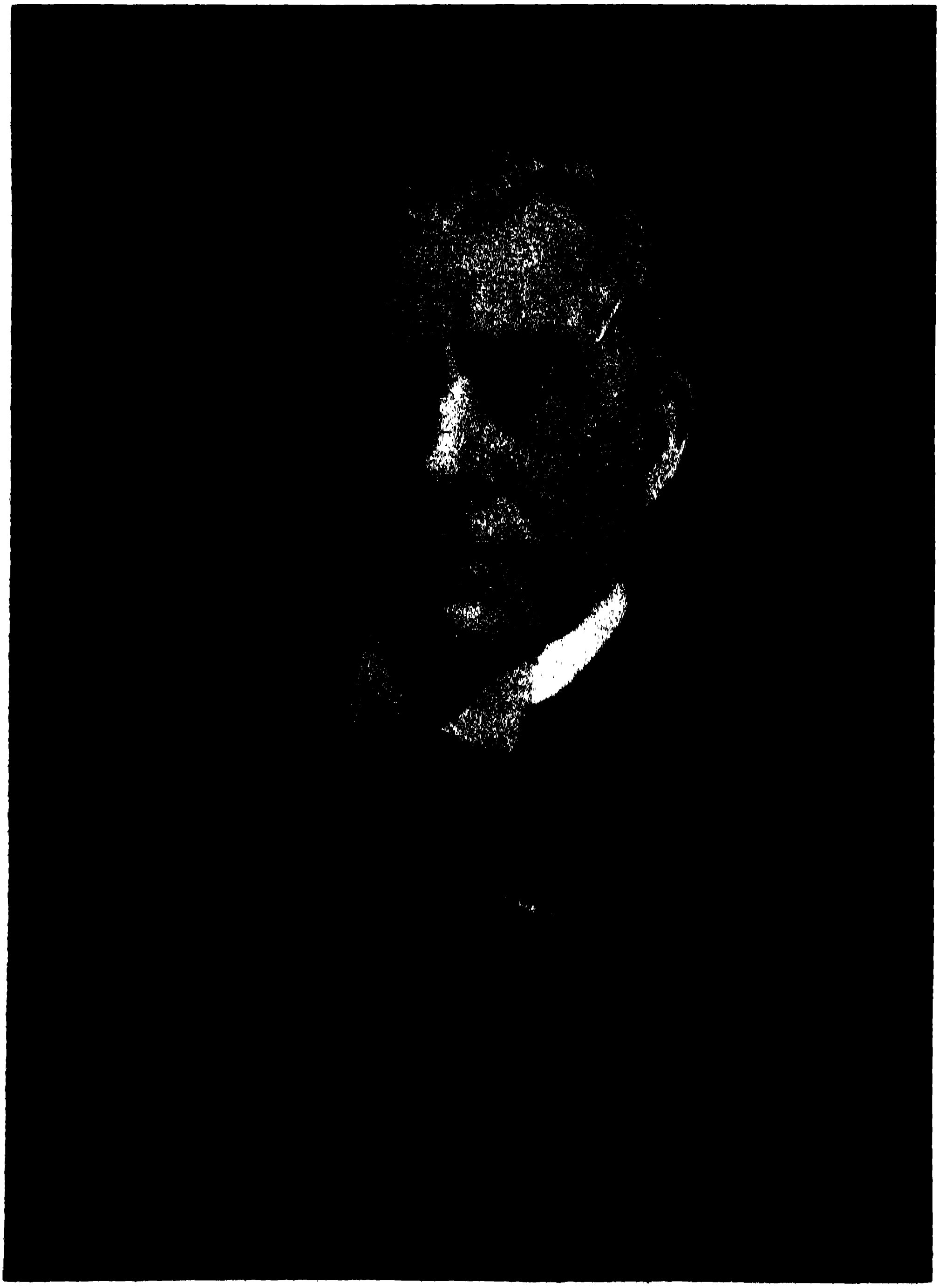
[1] Journal Series paper of the New Jersey Agricultural Experiment Station, department of soil chemistry and bacteriology.



PROFESSOR M. W. BEIJERINCK AT THE AGE OF SEVENTY with them will not doubt that he has opened as many new fields and has advanced our knowledge considerably in all of them. It is sufficient to mention his studies on the formation and genesis of buds and roots, as well as the general problem of regeneration in the field of plant anatomy; his studies on the phenomena of the plant-root galls and tobacco mosaic in the field of plant pathology; his discovery of legume bacteria, of the non-symbiotic nitrogen-fixing Azotobacter, of sulfur-oxidizing and sulfate-reducing bacteria, of nitrate-reducing bacteria and numerous others, in the field of soil microbiology and plant nutrition; his studies on the butyl-alcohol forming and butyric acid bacteria, the lactic and acetic acid bacteria, and the microbes concerned in the retting of flax, in the field of industrial microbiology; his studies on the nutrition of algae, amoebae and microbes in the field of general microbiology—to recognize the far-reaching and extensive contributions of this scientist.

Beijerinck was the pioneer to open up new fields for others to exploit and to follow. He had a keen mind and a great ability for observation. His methods of experimentation were always simple. He always devised new and very effective methods of investigation. The writer well recalls a visit to Beijerinck in the summer of 1924. Beijerinck was then already living in retirement for a period of three years, but was still able to prepare, by means of a few simple pieces of apparatus that one can devise in a country home, several experiments with Azotobacter and a few other bacteria, so as to have something to discuss.

PHOTOGRAPH TAKEN IN PROFESSOR BEIJERINCK'S GARDEN, AUGUST, 1924

PROFESSOR BEIJERINCK
IN HIS GARDEN (AUGUST, 1924)

In 1921, Beijerinck's numerous pupils, friends and admirers combined to celebrate his seventieth anniversary, and published on this occasion all his contributions to science in five volumes, which stand as a monument to his accomplishments. He was elected as honorary member by numerous foreign scientific institutions, as a sign of their homage to his genius.

Beijerinck had a very sensitive nature

and one had to come in very close touch with him to recognize how faithful a friend he could be. His personal life was very retiring. Never married, he lived for many years with his unmarried sisters, to whom he was very much attached.

A personal observation may well illustrate this point. This occurred on the occasion of the author's visit to Beijerinck's home, near Gorssel, in 1924. A very delightful morning was spent in discussing various problems in the field of microbiology, as well as Beijerinck's own impressions of Pasteur and other investigators in this field. This was followed by lunch, in which Beijerinck's only surviving sister and the writer's wife participated. The professor himself was rather somber, but his sister, who has evidently learned her English by reading Elizabethan writers, and not only scientific literature, enlivened the conversation considerably with various stories of their former and present life. Lunch finished, and the weather being rather pleasant, the group retired to the garden, where Beijerinck was still carrying on some experiments on plant breeding. The writer then begged permission to use for one moment his camera, so as to carry away a souvenir of this memorable visit. Beijerinck, however, declined very decidedly to pose or to even allow a rapid snapshot to be taken. "It is something I never allow to do," he stated in a tone that permitted no further discussion of this subject. However, a memento was to be taken at any price, so the writer proceeded to photograph the famous garden, to which of course the professor could see no objection. Miss Beijerinck, watching these proceedings with seeming amusement, willingly agreed, at the invitation of the amateur photographer, to pose in the garden. She immediately invited the other two ladies of the party, one of whom was the housekeeper, to join in this photograph. After the ladies were all ready and the camera was about to click, Miss Beijerinck turned to her brother, who was watching the proceedings from the doorsteps, and said, "You see, we are all going to be in the picture, and you are the only one not in it; perhaps you would better join us." He could not decline this invitation, and after covering his head with a cap, he joined the group. After the group photograph, no further objection was raised to an individual one.

Although he officially left his laboratories about ten years ago, Beijerinck could not bring himself to give up active investigation altogether. His old love for botany was now revived, and in June, 1927, he submitted a communication to the Royal Academy "On the Position of the Leaves," a subject treated by him forty years previously, namely, in 1886. He also attempted to correlate certain phenomena in bacteriology, such as "chemo-synthesis" with "denitrification," and to deduce from these a general law of bacterial development. However, he was primarily a keen observer, who could deduce from his simple experiments important facts.

As is the case with many men of genius, once he postulated a theory, it was difficult for him to give it up, even in the face of accumulating contrary evidence. This was the case of the mechanism of fixation of nitrogen by leguminous plants. "What is your opinion?" he asked the writer. "Does the plant or the bacterium fix the nitrogen?" The writer was rather astonished, having felt all the time that the rôle of the bacterium in this process was recognized as definitely established. "Not at all," continued Beijerinck, "and it will be left for you younger workers in America, who are free from the prejudices that we are enveloped in here, in Europe, to take up the problem again and settle it definitely."

As one of the greatest microbiologists that ever lived, his loss will be felt throughout the civilized world.

Selman A. Waksman

THE SCIENTIFIC MONTHLY

OCTOBER, 1931

BELGIAN CONGO SANCTUARIES

By MARY L. JOBE AKELEY, A.M., F.R.G.S.

SECRETARY OF THE AMERICAN COMMITTEE FOR SCIENTIFIC RESEARCH IN THE PARC NATIONAL ALBERT

HAVING already established the first national park in Africa, the Parc National Albert, in the Belgian Congo, Belgian conservationists are now planning to extend their unique sanctuaries for conservation and research to other fields in the Congo. Parc National Albert comprises 500,000 acres; Parc Leopold and Parc Ruwenzori, the new projects, will add, respectively, 1,000,000 and 500,000 acres to this great park system. In America, where our great national parks attract visitors from all over the world and inspire foreigners to emulation, the addition of two such areas as these would appear to have but little importance. However, the significance of the Belgian park idea lies not only in the fact that it led to the creation of the first parks in Africa, but also to the first parks in the world to be established for purely scientific purposes.

This complete sanctuary for wild life in Africa, the Parc National Albert, was established by royal decree of Albert, King of the Belgians, in 1925. Here, in the Kivu District of the Belgian Congo, near the geographic center of the great continent, are found many interesting animals, chief among which is the rare mountain gorilla (*gorilla gorilla berengei*), to-day of increasing importance, not only to scientists but also to lay students of the wilds.

On the cool wooded slopes of the extinct volcanoes and ranging side by side with the gorilla and at peace with him are herds of elephant and buffalo; here, too, are leopards which sometimes menace the gorilla's young. In the lower lands—the sandy plains and swampy lands bordering one of Kivu's great lakes, Lake Edward, are herds of antelope such as frequent the wide plains and rolling uplands of British East Africa. In the deep, slow-flowing Rutshuru River and in Lake Edward are herds of hippo thriving and increasing under a hot tropic sun.

Of all the highly diversified regions which represent all the zones of climate of the earth and which are now included in the Parc National Albert, the gorilla's wilderness home is by all means the most impressive. The landscape is startlingly beautiful. Giant forest monarchs crowd upon each other, their gnarled and long moss- and fern-hung branches touching and intertwining, their massive trunks, draped in long flowering banners of gray-beard moss or pale green vines, starred with golden flowers. Here and there, in crannies of bark or in the moss, brilliantly colored orchids flourish. Round about is an almost impenetrable undergrowth brightened by blossoms of many hues. The leafage of the forest, the masses of glistening leaves that top the great trees, gleam in the fitful sunlight in many changing shades of creamy yellow, aquamarine and emerald. Never elsewhere have I seen the foliage of a forest of so many variant shades of green.

—*Photo by Mary L. Jobe Akeley*

KARISIMBI

One of the peaks of the Parc National Albert, Belgian Congo, in fresh snow. The wildly beautiful forest that covers the slopes of this mountain and its sister peaks, Mikeno and Bishoke, is the characteristic home of the gorilla.

This gorilla forest occurs at an altitude of 9,000 to 12,000 feet above sea-level. Once in a long while, from a vantage point on some volcanic rampart, you can see a wide and impressive view. One such was on the slope of Karisimbi, a mile from our camp, where in 1926 I spent six weeks, collecting and studying the habitat of the mountain gorilla. Here, in a break in the trees, we could see to our right the rugged massif of Mt. Mikeno. Three thousand feet below stretched the wide expanse of lava plain, an outflow in recent geologic times from the active volcanoes, Nyiragongo and Nyamlagira, whose massive cones, topped by glowing, amber-colored clouds, cut the far horizin. Below them to the southward stretched the pale blue sheet of Lake Kivu, glittering with the reflection of the glowing sun as it sank into the hinterland. It is in this environment of age-old forest that the gorilla has established his home.

The attention of scientists as well as of nature lovers was directed to this remote part of the world by the late Carl Akeley, naturalist and conservationist, following his 1921–22 expedition for the American Museum of Natural History. There in the untouched wilds of the Congo he secured a group of gorillas for a natural history exhibit for African Hall. Unwilling to take any life needlessly, he collected only five—one half the number of specimens permitted him by the Belgian Government—because he believed this number sufficient to serve his scientific purpose. While collecting these specimens, he observed the gorillas at close range and accordingly became impressed by the non-combative nature of the gorilla when undisturbed by man.

Mr. Akeley was greatly surprised by the small number of gorillas inhabiting the forested slopes of the three extinct volcanoes, Mikeno, Karisimbi and Bishoke, in which they had been reputed to be plentiful. He knew that many "mighty hunters" of big game were at that time eager to hunt and kill gorillas because they craved a new sport—new hunting trophies for their collections. Realizing that because of the nature of the gorilla and the scarcity of the animal it would be an easy matter to exterminate the whole colony, he began to advocate the protection of the gorilla as well as of all other wild life, both plant and animal. Upholding and actively assisting him in his plea were Dr. John C. Merriam, president of the Carnegie Institution of Washington, and Mr. James Gustavus Whiteley, Belgian consul general at Baltimore.

It was in January that Mr. Akeley wrote to Dr. Merriam, expressing his great desire that the Belgian Government might set aside an area wherein the gorillas might be permitted to live in complete security. He also advocated the eventual establishment of a scientific research station, located in close proximity to the gorilla mountains and the live volcanoes, with their rich and varied opportunities for study.

Dr. Merriam immediately recommended this gorilla sanctuary plan to Baron Emile de Cartier de Marchienne, then Belgian ambassador to the United States, who took it directly to King Albert for consideration. The King was impressed by the extreme desirability of the measures advocated, and in 1925 he created the Parc National Albert. This royal decree was approved and commended by individual scientists and conservationists interested in this Congo wonderland. Only professional hunters of big game were disappointed, since they could no longer kill the big anthropoids for trophies.

Scientific bodies soon voiced approval. In April, 1925, the National Academy of Sciences expressed in resolution its "gratification at the action of His Majesty, the King of the Belgians, in the establishment of the Albert National Park for the effective preservation of the

—*Photo by Mary L. Jobe Akeley*

GORILLA NEST

—*Photo by Mary L. Jobe Akeley*

GORILLA NEST

gorilla and other animals, together with the protection of the flora of the region," and assured His Majesty of its "deep interest and disposition to cooperate in the realization of the benefits to science and mankind arising from this wise and generous action."

Shortly after the creation of the Parc National Albert, my husband requested Belgian permission, through Baron de Cartier, to return to the Kivu to secure studies for a painted background and accessories for his Gorilla Group stating that he had delayed asking permission to do this work, pending the establishment of the gorilla sanctuary. It was also his desire to carry on initial investigations of the gorilla in his native haunt. His request was readily granted, and this undertaking became one of the objects of the Akeley-Eastman-Pomeroy African Expedition of the American Museum of Natural History.

While en route to Africa in February, 1926, my husband and I went to Brussels, where we were entrusted with the royal mission to the Kivu, which empowered us to execute a general survey of the National Park; to fix on the map native villages, position of forests, bare rocky country, grass lands, cultivated land and pasture, and areas inhabited by gorillas and chimpanzees; to estimate the number of these animals; to study methods of preservation of the fauna, especially the gorillas; and to select suitable sites favorably located and naturally endowed for laboratories and residences for park conservators and visiting scientists. Later we invited Dr. J. M. Derscheid, zoologist and cartographer of Brussels, to join us in Africa to assist with this survey. After my husband passed to the Great Beyond, only three days after we reached his old 1921 camp in the gorilla forest, Dr. Derscheid's painstaking efforts made it possible for our expedition to fulfil the royal mission of the Belgian Government and to prepare a definite and comprehensive report.

—*Photo by Mary L. Jobe Akeley*

GORILLA NEST

Returning to Europe, I was requested by King Albert to go to Brussels, where I gave him a preliminary account of the

—*Photo by Mary L. Jobe Akeley*

THE *HAGENIA ABYSSINICA* ("PAPER BARK TREE")

IS ANCIENT, HUNG WITH CLUMPS OF PARASITIC FERNS AND DECORATED WITH PLATFORMS OF VELVETY MOSS AND PINK ORCHIDS.

results of our expedition. Derscheid, reaching Belgium in June of 1927, went almost immediately into military service, but he was at the same time preparing an initial report on his gorilla findings and correcting and amplifying the maps of the region between Lake Kivu and Lake Edward. In the autumn of 1928, during four weeks in Brussels at the home of Dr. Derscheid, we collaborated on the preparation of recommendations for the Belgian Government concerning the future of the Parc National Albert.

As delineated by the original decree of 1925, the park was confined to a triangular area comprising the three extinct volcanoes, Mikeno, Karisimbi and Bishoke. We now proposed that this area be extended to include the arid active volcanoes, Nyamlagira and Nyiragongo, of great interest to geologists and seismologists; that it should also include the swamps and sandy lands along the southern shore of Lake Edward and the Rutshuru River, where animal life is abundant; that certain native villages and arable lands be excluded in order to preclude the possibility of future conflict between native rights and the material development of the country on one hand and the interests of science on the other; and, for the promotion of scientific research, that there should be established a central station for research and administration, including laboratories, library and study museum, and also that ranger stations should be built throughout the park. In conclusion, we recommended that the management of the park be placed in the hands of a scientific institution so favorably situated as to obtain financial and scientific help both in Belgium and in foreign countries.

Our report, approved by His Highness Prince Albert de Ligne, until recently Belgian ambassador to America, and by Baron Emile de Cartier de Marchienne, now Belgian ambassador at the Court of St. James, was submitted with hearty recommendations to King Albert when he received us at the Royal Palace on October 8, 1928. There, throughout a long and interesting evening, the project of the park was discussed. Dr. Derscheid gave an account of the Akeley-Derscheid expedition and projected photographs of the Kivu. I had taken with me to Brussels the gorilla film which Mr. Akeley had made in 1921 in the Kivu, the first motion pictures ever made of live wild gorillas, and this also we showed to His Majesty and to His Royal Highness Prince Leopold, who had recently visited the Kivu volcanoes.

The following May came the royal decree of May 6, 1929, which increased the Parc domain to 500,000 acres, and provided therein for the preservation of all fauna and flora for strictly scientific purposes. The newly added territory included Lake Edward, in the northern part of the Kivu District. Lake Edward is much lower in elevation than the gorilla country. Its shallow, turbid waters teem with animal life; its shores and adjoining grassy, sandy plains are hot, affording range lands for large herds of antelope, all the species found in East Africa, and found nowhere else in the Congo; its swamplands and affluent rivers harbor herds of hippo (*Hippopotamus amphibius kiboko*).

The decree of 1929 also stipulated that the Parc is to be administered by the Commission du Parc National Albert, under the presidency of His Highness Prince Eugene de Ligne, and by a committee of direction. In the park, it is forbidden under penalty of penal servitude, or fine, or both, to pursue, capture, kill or molest in any way any kind of wild animal, including animals which are reputed harmful; to take or destroy the eggs of wild birds; to cut down, destroy or remove any uncultivated plant; or to make any excavation, embankment, boring or any operation of a nature to change the aspect of the ground or of the vegetation. Unless provided with a

—*Photo by Mary L. Jobe Akeley*

M'GURU, GORILLA GUIDE

IN MOSS-COVERED TREE, WHICH WAS BROUGHT TO AMERICA BY MRS. AKELEY AS AN ACCESSORY FOR THE GORILLA GROUP FOR AKELEY AFRICAN HALL.

special permit, no one (except officials and others properly qualified) may enter the park, or circulate, camp or sojourn therein, or introduce dogs, traps or firearms, or possess or transport or export skins or other parts of wild animals, or uncultivated vegetable products. Lands now occupied by natives or private persons are to be expropriated. Even on these tracts under private or native occupation, the destruction, capture or pursuit of the gorilla as well as all forms of hunting this animal are absolutely forbidden.

Around the park proper are areas which serve as a protecting zone. Cutting down trees, hunting and fishing are prohibited in this zone. A few natives now living therein will not be deprived of their hereditary rights, but they may employ only their primitive weapons. The Belgian Government will pay the strictly administrative expenses of the park, maintaining a corps of conservators and native police.

In October, 1929, King Albert formally installed the Commission du Parc National Albert, which is a body of eighteen scientists chosen from England, Sweden, the United States, France, the Netherlands and Belgium. In his address at the Palais des Academies, Brussels, His Majesty described the park as unique because of its widely diversified scientific opportunities. He emphasized the varied aspects of the region which are of interest not only to geologists and mineralogists, but which are remarkable from the point of view of ethnography as well, since Bantu and Hamitic tribes as well as pygmies (Batwa) are simultaneously present; and by no means least remarkable, from the point of view of biology, since the wide range of its altitudes allows several life zones to meet and gives rise to flora and fauna infinitely rich and varied.

"No other region of the African continent," said His Majesty, "offers such wide opportunity for scientific study and for the installation of scientific research stations which would be easily accessible in a climate ideal for the white race."

Then, in 1930, the American Committee for the Parc National Albert was formed to cooperate with the International Committee in the work of scientific research. His Highness, Prince Albert de Ligne, at that time Belgian ambassador at Washington, who from the beginning has taken an active and energetic part in forwarding the plans for the Parc, was named by His Majesty chairman of the American committee; Mary L. Jobe Akeley was appointed secretary. In addition to the two American members of the International Commission, Dr. Henry Fairfield Osborn and Dr. John C. Merriam, Prince de Ligne has appointed as members of the committee Mr. Stanley Field, president of the Field Museum of Natural History, Chicago; Dr. Vernon L. Kellogg, of the National Research Council, Washington; Dr. Robert M. Yerkes, of Yale University; Dr. George W. Crile, of Cleveland, and the Hon. James Gustavus Whiteley, Belgian consul general at Baltimore.

At a meeting of this committee, held recently at the American Museum of Natural History, New York, Prince de Ligne, who was leaving America to take up his duties as Belgian ambassador at Rome, resigned his office. Dr. Merriam was elected president to succeed him. At this time, it was decided to enlarge the American committee in order to afford a national representation. The committee's purpose now is to bring the Parc National Albert and other similar undertakings in Belgian Africa in closer contact with American scientific and conservation organizations, as well as to secure support for these projects.

Dr. J. M. Derscheid, now administrator-general of the Parc, was present at this meeting and reported to his colleagues plans for the further extension of the park system in Belgian Africa,

—*Photo by Mary L. Jobe Akeley*

GORILLA GROUP IN AMERICAN MUSEUM OF NATURAL HISTORY

MOUNTED BY CARL AKELEY.

and told them of the progress of the Kivu park. In addition to the Parc National Albert, there will be created a new park, Park Leopold, near the northern border of the Congo. It will comprise an area of 1,000,000 acres. Lying north and east of Parc National Albert will be another new park, the Parc Ruwenzori, an area of 500,000 acres in the Ruwenzori Range, adjoining the Belgian Congo-British Uganda Boundary. These new regions are of particular interest to scientists since they are the home of such rare mammals as the white rhino (*Ceratotherium cottoni*); the okapi (*Okapia johnstoni*); the giant Derby eland (*Taurotragus gigas*); and lechwe, Mrs. Gray's antelope (*Onotragus megaceros*). Here also occur such interesting birds as the secretary bird, (*Sagittarius serpentarius*); the hornbill (*Lophoceros melanoleucos stegmanni*); the Gelo River crowned hornbill (*Pophoceros melanoleucos geloensis*); the Ruwenzori lourie (***Ruwenzoriis johnstoni johnstoni***); the Uganda brown parrot (***Poicephalus myeri saturatus***); the Southern little bee-eater (***Melitto-***

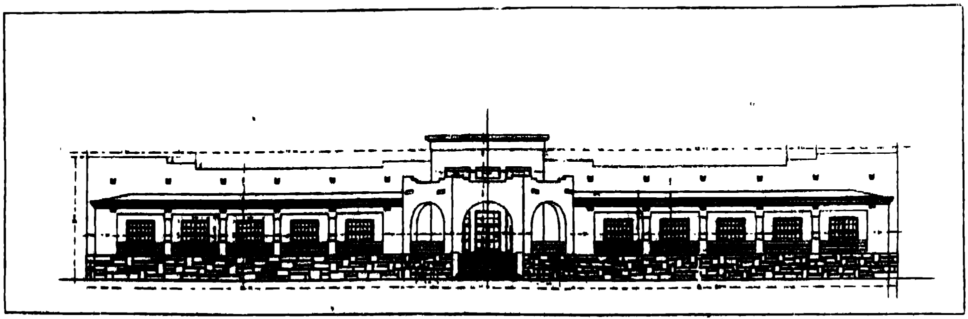
phagus pusillus meridionalis); the Ruwenzori Kakelaar or wood hoopoe (*Phoeniculis purpureus ruwenzorae*); the Swahili wood owl (*Strix woodfordii suahelica*) and many others.

Pending the official establishment of these new parks, activity has been concentrated in the Parc National Albert. Patrols of native scouts are on guard to prevent the killing of any wild animal and the destruction of plant life. Meanwhile the Belgian Government has appropriated ample funds for the maintenance of the Park Service, and has advanced a loan of two million francs, to begin immediate construction of a central station for scientific research. This station will be erected on a grant of twenty acres in the heart of the government post at Rutshuru. The buildings will rise on the banks of the deep-flowing Rutshuru River, and will give a broad view of both active and extinct volcanoes. The station is in the geographic center of this naturalist's paradise.

Here will be the central library, containing a collection of all the scientific treatises relating to the fauna, flora and geology of Central Africa; a study museum, for which will be collected all the animals indigenous to the immediate vicinity; laboratories, equipped for the use of zoologists, botanists, seismologists and geologists. Adequate provision, as well, is being made for a chemical laboratory and a photographic wing. Nearby will be an assembly hall, administrative offices and living quarters. All these buildings are designed for the use of white men unaccustomed to the tropics. Although barely one degree from the equator, Rutshuru is actually white man's country, because its 5,000 foot elevation brings it out of the torrid zone.

This central station, moreover, will very shortly be connected with the outside world by a motor road to Redjaf-on-the-Nile, and thence by water and rail to the Mediterranean. Another road will connect with Kisumu, and thence by train to Mombasa, the port of entry on the Indian Ocean. However, quickened avenues of approach to this region will by no means result in letting down the barriers into the Parc, so far as the outside world is concerned. One of the most important points in the scientific creed of the Parc is that therein the primitive shall be preserved! Accordingly, the natural conditions in the Parc will not be disturbed by contact with grazing or agriculture; and, lest the fauna become half-domesticated by the familiar presence of man, certain limited areas will be set aside, free from human intrusion except as emergency may require.

In our great American national parks, animals are all too often semi-domesticated. Bears, demanding sweetmeats or manufactured food, "hold up" passing



PROPOSED RESEARCH STATION

TO BE BUILT IN THE PARC NATIONAL ALBERT, BELGIAN CONGO.

motor cars; they live in the main on hotel refuse, and are in many ways changed from their primitive ancestors in general behavior psychology and even in physiological habits. Such a state of affairs will never be permitted to exist in the Parc National Albert. Only scientists will frequent the Parc, and even they are barred from at least one quarter of its area. Thus, the gorillas of that region, as well as other wild species, will not become accustomed to man, and thereby influenced or changed by contact with him.

This intention to preserve the primitive, wholly unaffected by the aggressive march of civilization, is indeed a recent attitude. It is the spirit motivating those who now carry on the fight to save vanishing Africa. Theirs is not a sentimental interest. It is a sympathetic understanding and a realization of the urgent need for action. In Africa, at least, Carl Akeley's dream, now become a reality, has halted the juggernaut of mass destruction. Belgium's wholehearted response is an epochal instance of the international possibilities of conservation and of scientific inquiry. Such liberal and broadminded action will go far toward cementing national friendships.

Thus, through an action of extreme generosity and cooperation, the resources of Belgium's scientific wonderland in the Congo have been thrown open to scientists from all over the world. We are confident that they will not be slow to take advantage of these unparalleled opportunities for serious research. Furthermore, it is earnestly hoped that sympathetic laymen, in America as well as elsewhere, will come forward to assist in the rapid completion of the great central station. Such practical and friendly support will be at once an aid to the progress of science and an important material contribution to the conservation of wild life under conditions of rare and compelling interest.

SOME OF THE BIOLOGICAL EFFECTS OF DROUGHT[1]

By Professor HARLEY J. VAN CLEAVE

UNIVERSITY OF ILLINOIS, URBANA

MANY conservation agencies have been active in calling attention of the public to the peculiar problems confronting the movements for conservation growing out of the period of excessive drought which spread over large portions of our country during the summer of 1930. Through the agency of the U. S. Biological Survey, information on the dire effects of drought upon the water fowl in their nesting sites has been pictured, and a decrease of at least 50 per cent. in the season's hatch of water fowl has been estimated for some of the most favorable breeding grounds. Likewise, the U. S. Bureau of Fisheries has given forth information on the effect of the dry season upon the fish life of our lakes and streams. The American Game Protective Association has given publicity to the appalling situation with regard to the larger game mammals and birds. Furthermore, many other investigations carried on by federal and state agencies and by private individuals combine to give the public a fair basis for understanding that a definite crisis faces all our larger species of wild life as a consequence of the extreme drought which, in many parts of the country, extended throughout the summer and winter of 1930–1931. Little has been recorded of other aspects of this problem because the public is interested chiefly in the game birds and animals; for conservation to many people means only the protection of the interests of the hunter.

Important as this aspect may be, the biologist views the larger creatures such as the game animals, birds and fishes as only links in the complicated chain of relationships which exist between all the forms of life in a given region. Consequently, to the student of biology, the effects of a severe water shortage are but imperfectly measured if only the large, conspicuous animals are considered. The importance of the smaller organisms, even down to the microscopic plant and animal life, in the food chains of all animals, makes it especially important that these less conspicuous beings should receive consideration in any adequate picture of the effects of drought.

To most people it might seem that first man, then vegetation and aquatic life are the chief if not the only drought sufferers in nature. A zoological collecting trip through southern Illinois during September, 1930, gave pronounced evidence of the effects of continued dry conditions upon some of the less conspicuous forest animals. Previous studies had shown that the region visited had been especially favorable for the development of two types of animal life which might be especially susceptible to the effects of prolonged drought, namely, the land salamanders and the land snails. Exact quantitative data are not available for a comparison between normal and drought years. But the contrasts were so evident that it seems worth while to record them here, even though numerical data are lacking. In woodlands (chiefly oak, hickory and maple) with considerable amounts of down timber that has been lying on the ground for some time, the soil and accumulated humus beneath logs provide an especially favorable habitat for land salamanders and land snails. In a normal year ten or fifteen minutes of examination beneath logs might, on the average, yield one or two salamanders and perhaps a dozen snails. Woodlands of southern Illinois where such collecting conditions have been known to exist previously were revisited in September, 1930, and in numerous examinations over a wide area covering a period of five days, a single salamander was seen and a total of not more than a dozen living snails was observed. Dead snail shells were taken in great abundance, and especially those from under logs gave mute evidence of the extent to which mice and other rodents had preyed upon the snails seeking shelter beneath logs where the last vestiges of available moisture were to be found.

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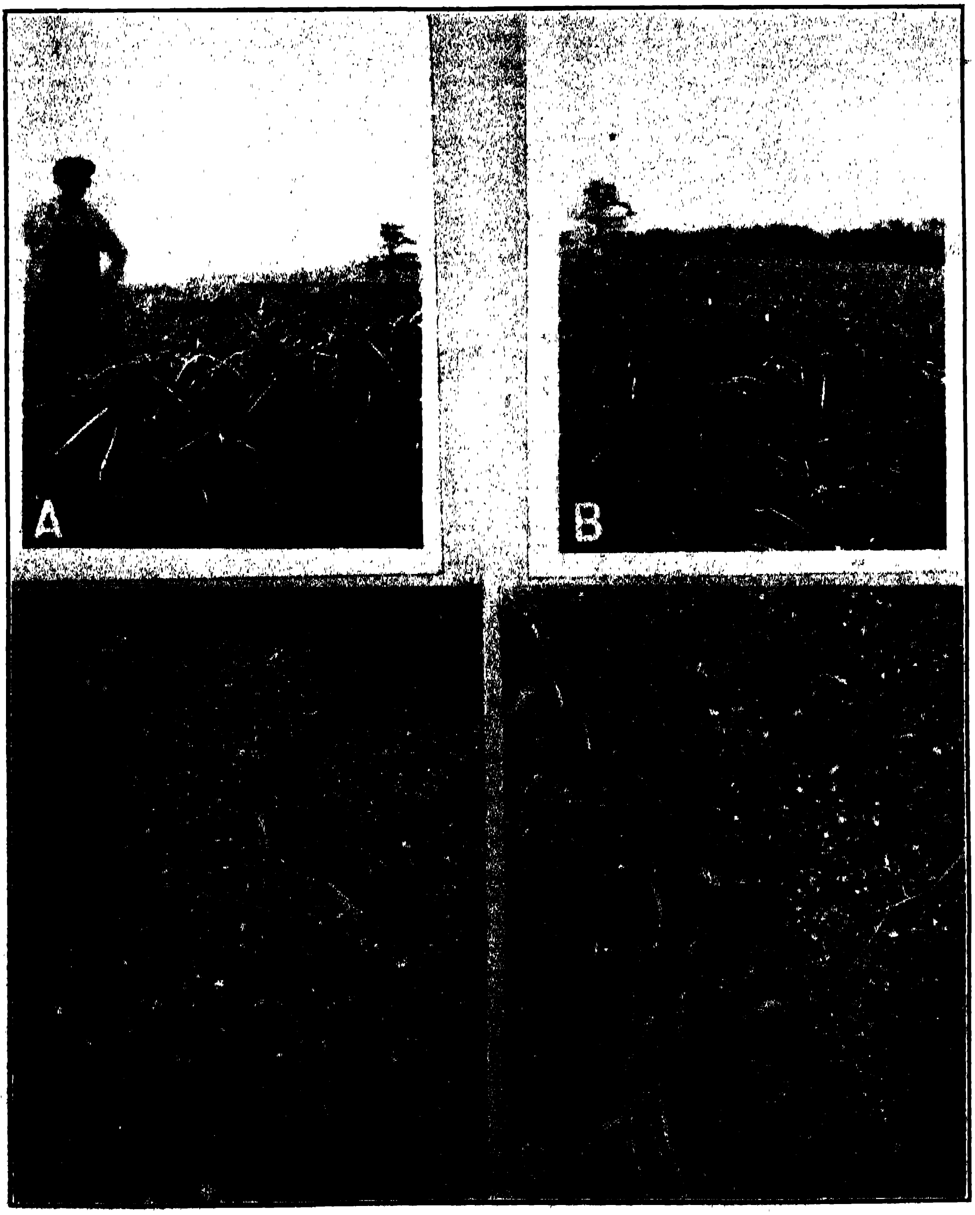
[1] Contributions from the Zoological Laboratory of the University of Illinois, No. 403.

Recent rains had furnished sufficient surface moisture on the floor of the forests to stimulate activity of the snail population if the snails had been simply estivating. The lack of active snails and presence of dead shells gave conclusive evidence that the land snail population had been very seriously decimated as an accompaniment of the drought and conditions associated with it. By way of an attempt at expression of relative abundance, the living snails were estimated as present in numbers less than one per cent. of the numbers present in the same habitats at the same season following a favorable summer. The failure to find salamanders in usual abundance might be explained by the greater readiness with which these animals may migrate from unfavorable conditions. It is entirely possible that crevices or mouse runs, especially in ravines or in the vicinity of springs, may have sheltered salamanders and account for their absence from their usual habitat. Though extended search was conducted for such refuges, none were found.

Fire as an accompaniment of the drought conditions added to the severity of toll of life in many localities visited. The tinder-like grass and dead vegetation when burned gave eloquent testimony of living sacrifices to the god of rain or the demon of fire. Charred bodies of snakes and rodents were seen in the burned-over areas, dried mummies of salamanders were found under stones and logs, and burned, fragile snail shells were strewn among the lifeless ashes.

The right-of-way along railroads has for some time been proclaimed as sheltering a surviving remnant of our typical prairie flora. The railway embankments themselves are not a relict of primitive conditions, but on the contrary furnish a highly artificial set of conditions provided by the grade and the largely foreign ballast material. Even after the period of excessive drought, the roadside, the railway right-of-way and even the artificially formed embankments provided more favorable conditions for the collection of living land snails than were discovered in any of the natural wooded areas studied. The excessive exposure to sun and wind, and the poor conditions for retaining moisture would seem to render the railway embankment decidedly unfavorable, but here living land snails were found in abundance sharply in contrast with that of woodlands and meadows. Chiefly nocturnal in habits, these snails during the day seek shelter under pieces of wood or bits of stone. In one instance a piece of wood about 3 by 5 inches served as the shelter for more than 60 living snails, most of which were at least 8 mm in diameter. The species of snails living in this new habitat are by no means limited to a few. They are the forms of the region which previously were characteristic of the meadows and woodlands. They include several species of Polygyra and Gastrodonta, as well as numerous species of the smaller pupoids and zonitoids.

Though drought seems to have exercised little influence upon the snails along railway embankments, fire had imposed a heavy toll of life. Many dead animals were found on portions of the right-of-ways that had been burned



SOME OF THE BIOLOGICAL EFFECTS OF DROUGHT

Figs. A and B. The site of Horseshoe Lake in southern Illinois after the water had completely disappeared. The trees in the background mark the location of the island. Photographs taken in September, 1930, by Miss Hilda Stein.

Figs. C and D. Results of combined action of drought and pollution on snail population of the Illinois River above Peoria. In February, the heaps of shells were much higher than shown in these pictures which were taken in May.

over as per custom of railway maintenance. In such regions only an occasional survivor was found beneath stones or heavy timbers. Repopulation of these burned areas must come largely by invaders from the surrounding unburned areas. Advocates of conservation have here an added argument in favor of repeal of state laws and regulations stipulating that railroads must periodically burn over their right-of-way, for not only is the remnant of our native flora thereby endangered, but all sorts of animal life suffer at the same time.

The effects of the drought in many regions of central and southern Illinois were no less pronounced for the aquatic life than for terrestrial beings. In many regions streams and ponds which have been considered permanent were wholly dry since early in June or July and remained dry until in March. For these the drought conditions spelled practically the extermination of all forms of aquatic life. In many instances, all the fish life, even including the game fishes, was wiped out from entire lakes, ponds and streams. Unfortunately, little was done in the state of Illinois to avert such catastrophes. One of the major casualties was at the site of Horseshoe Lake in southern Illinois near Cairo. Here a state conservation preserve, comprising 1,335 acres of water surrounding an island of 1,172 acres, became the most desolate monument to the effects of drought and failure to apply adequate rescue programs. As reported in a communication to *Outdoor America* for December, 1930, this lake with its inestimable promise as a region for perpetuating natural conditions in the Ozarkian region of Illinois disappeared completely, and with it went the lives of millions of fish, to say nothing of all the other aquatic animals which it sheltered.[2] Here before the catastrophe of 1930, fishes, birds, snakes and turtles were in the greatest abundance that the writer has ever observed in any area within the state of Illinois. The bleached bones of all but the birds, and the shells of mussels and crayfishes which strewed the former lake bed in September gave corroboration of the graphic descriptions of the death and putrefaction described by those residing close to the lake, and spoke eloquently of the myriads of smaller forms of life which must have perished at the same time.

Even temporary ponds which play such an important rôle in the life of amphibians and crustaceans, especially the fairy shrimps, have remained dry throughout the summer and winter and have not afforded the customary habitats for the breeding of salamanders and other early spring amphibians. The burrowing animals, such as the crayfishes and earthworms, doubtless have an important part in creating conditions for the carrying over of stock for temporary ponds, for they often construct burrows which deepen to ground-water level as the ponds dry up. Thereby numerous forms of animal life doubtless find refuge and remain as a stock to repopulate the pond when surface water makes its appearance and through the worm or crayfish tunnels brings the ground water again in continuous relation with the surface water.[3]

Press reports throughout the summer and winter of 1930–31 cited many instances of failure of wells and reservoirs and the serious curtailment of water supply for household and industrial purposes. The inconvenience and the economic losses incident to the failure of a water supply are clear to the minds of most people, but little has been said of the biological significance of such water famines. One instance has been studied in more than usual detail by Dr. David H. Thompson, of the Illinois State Natural History Survey. For a civic water supply the city of Mattoon, Illinois, depends upon a reservoir of approximately 175 acres, known locally as Paradise Lake. This reservoir was known as an especially favorable habitat for fishes, and earlier surveys had revealed a rich and varied population. By March, 1931, the water area of this lake had been reduced to less than 10 acres. At this stage, Dr. Thompson made a survey of the fish life and has given consent to the use of some of his unpublished observations. He found that in the biological struggle that accompanied the shrinkage of the waters all the small fish had disappeared, and none but the large game fish survived. Eye witnesses of the progressive stages are not required for the reconstruction of the scenes in the struggle of elimination and survival which accompanied the restriction of the habitat. Competition for the natural food supply on the forage grounds gave way to predaceous habits and cannibalism which terminated in the survival of a few individuals out of the varied population. Similar reductions and complete exhaustion of stored water supplies were reported from many regions throughout the drought area. Every instance must have been marked by corresponding reductions in the animal life, though human inconvenience and economic losses loomed so large in the picture that few could look beyond them to an appreciation of the losses to conservation.

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[2] Word has been received that the Department of Conservation of the state of Illinois has constructed a new dam at the Horseshoe Lake site and that plans for restocking the new lake are under way.

[3] Since the above was written, the author has seen the very interesting memorandum by E. P. Creaser "Some Cohabitants of Burrowing Crayfish," *Ecology*, January, 1931. This short note is one of the most significant contributions to an understanding of the method of repopulating temporary ponds and of the establishing and distributing of subterranean aquatic faunas.

In discussing the effects of drought upon terrestrial habitats, attention was directed to the responsibility of fire of human origin for depopulating faunas already reduced by the direct effects of drought. Similarly, in the aquatic habitats, the dire consequences of reduced water levels were multiplied many times over by the addition of sewage to the waterways. Rivers which have been able to carry a heavy load of sewage in normal years digesting the raw sewage and becoming self-purified as the water proceeded downstream were hopelessly unable to carry the same loads with decreased water flow. The Illinois River, for example, in the vicinity of Peoria, Illinois, was transformed from a river into an open sewer as an accompaniment of the drought of 1930. The sewage from Chicago could not be digested and consequently settled as accumulations at the bottom of the stream bed in all the quiet stretches of the river. These settling basins, acting exactly as settling tanks in a modern sewage treatment plant, were flushed out with each increase in diversion of lake water into the river and later in the winter by the rains and snows. In consequence, the putrid undigested sewage of Chicago was relayed by stages to regions far below the points where natural purification of the stream has occurred in normal seasons.

The total effects upon the animal life of the Illinois River are hard to estimate. Fishermen in the vicinity of Peoria report an appalling decline in the yield of commercial nets. A survey of the Illinois River from Peoria to Rome, Illinois, late in February, 1931, revealed conditions of low water and pollution that are hard to visualize. For miles at a stretch the stream in receding to a narrower channel had left wide margins of sludge banks whose filth was devoid of all evidences of life excepting those forms which live normally in sewage tanks and heavily polluted waters.

Because of the many cyclic factors

influencing the population of this river, as shown by the intimate studies of Forbes and Richardson covering more than four decades, exact quantitative expression of the combined effects of drought and pollution in the destruction of life is impossible. One of the most compelling evidences of the consequences of pollution of the Illinois River by sewage under the contributory hazard of low water is the countless number of dead snail and mussel shells lining the shores of the stream. From the city of Peoria northward, the receding waters throughout the winter have been heaped with drifts of dead shells. In February, 1931, these drifts were practically continuous shell heaps for the ten miles of the stream examined. Where wave action had not scattered the shells and where sludge had not buried them, the heaps of dead shells alone were frequently more than a foot deep and were more than two feet through at the base. The large, banded viviparous snail (*Viviparus contectoides*) was the most plentifully represented in these shell heaps, though numerous other species of snails and many bivalves were present. Of the snails, the gill breathers were the most seriously affected, in all probability because of the fact that the heavy load of sewage carried by the river used up all available oxygen, thus causing suffocation of the branchiferous animals. Several species of organisms which are known to be highly tolerant of sewage pollution were found living in the river. These included some of the pulmonate snails and fingernail shells.

Undoubtedly, pollution has been largely contributory to the loss of life of many kinds of aquatic organisms which might have been able to withstand the lowered water level brought about by the extended drought.

In conclusion, we know that many regions where moisture is lacking have characteristic faunas and floras adapted to the peculiar condition of the lack of water. The organisms which live habitually under these circumstances show many and varied adjustments to their surroundings. It is a common experience that organisms not adapted or adjusted to xerophytic conditions do not ordinarily survive long when introduced into them. For this reason, the excessive drought of the summer of 1930 holds much interest for the student of biology as a means of interpreting the effects of sudden and radical changes in the environment upon the life of the region affected. The process of natural adjustment to xerophytic conditions can not take place suddenly. In those forms which show natural adjustment, the change has doubtless been slow, either paralleling the changes in the environment itself or brought about as gradual modifications in organisms invading the area from surrounding regions of more nearly normal moisture conditions. The chief observable result of unusual periods of drought seems to be the material reduction of natural populations among the native species of animals. There is no apparent selection toward survival of the fittest in a single season. Consequently, the chief biological effect of a period of excessive drought is the imposing of a period of extreme depression in the population of all species affected. Such a period of depression will doubtless be of great influence in modifying the periodic cycles of increase and decrease in natural populations that have been so frequently observed by students of nature and correlated more or less satisfactorily with astronomical and meteorological periodicity. It remains for future studies to determine whether the reduced populations following the 1930 drought comes as one of the normal cyclic periods of population reduction correlated with major meteorological cycles or is an accessory period of depression imposed upon the normal periodic cycle in range of abundance of living things.

UNITS OF ENVIRONMENT

By Professor W. E. ALLEN

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FOR more than a decade it has been a considerable part of my business to give attention to environment and to problems of tracing and explaining environmental relationships. In practice, I have found it necessary to select as a point of departure some object or group of objects, and to examine a limited number of other objects, together with a limited number of entities and influences in relation to it. Under such limitations it seems impossible to avoid treating these particular objects, entities and influences as though they were units in the environment or units of the environment.

On the other hand, if I turn my attention to the general idea of environment, it becomes evident that there are no units either in or of environment. Exasperating and impractical as this view of the situation may be it yet has the merit of suggesting caution when one becomes too greatly impressed with his success in following clues to controlling influences.

So far as any thing or group of things is concerned, the universe is divisible into two parts, the thing itself and its environment. Constituting the universe as they do, these two parts are not wholes, but fractions having very essential relationships to each other and to the whole completed by them. If the thing designated be an electron, perhaps one may say that the thing (self) is indivisible while its environment is indefinitely divisible, but both are fractions of the universe, none the less. In other words self and non-self compose the universe, all that is not one being the other.

If one examines a thing different from himself he becomes a part of environment as far as that thing is concerned. Often he is the most important feature in study of environment, sometimes because he modifies the natural relationships between the particular self and environment and sometimes because he assumes that he has solved the problem of these relationships before he has reached comprehension of their extent or intricacy.

For single living things, or for any particular group of living things environment is so nearly the whole universe that it might be treated as a whole in practice were it not for the extreme ranges of differences amongst the parts into which it is divisible, differences in character, differences in degrees of influences depending on power, magnitude, duration and distance, and differences in directness of application of influence. These differences in the fractional parts of environment are both qualitative and quantitative and in respect to any particular situation it is often true that certain fractions carry great influence through their qualitative character rather than through their quantitative prominence.

Not least of the difficulties to be encountered in any and every attempt to assign numerical values to selected fractions of the environment is the impossibility of finding a system of measurement common to all. Supposing I observe a thousand increases in abundance of diatoms, from which I conclude that temperature is the "dominant factor" (fraction, in this context). My conclusion is based on a series of coincidences of evidences of increase in abundance with evidences of change in temperature within limits of what we call degrees, whereas heat may be only one of several influences acting together or nearly so. As a matter of fact there is not, even for other forms of radiant energy which may accompany heat, a system of measurement which enables us to compare accurately quantitative expressions of their separate influences on abundance. Still less are there systems of measurement which enable us to make quantitative comparisons between temperature and numerous chemical and biological influences. If we had such systems we might find that although temperature seemed most prominent its actual influence in promoting abundance was less than that of some other fraction operating jointly or at the same time.

In this connection we confront another difficulty which might not be wholly relieved by any harmonization of systems of measurement, that is, that temperature in a case like that mentioned may exert much of its influence in a roundabout-way through affecting closely associated physical and chemical fractions, or through affecting abundance and activities of closely associated organisms of other kinds. Similar reflexions of influence are also more or less distinctly characteristic of all other fractions in their relations to any particular self. Indeed, there is good reason for thinking that at times the reflected or indirect way of influence is most important. For example, rising temperature in spring may directly favor the growth of herbage in a mountain meadow, but the indirect effect through preventing entrance of grazing stock by torrential streams across its entrance due to melting snows may be still more favorable.

Then, again, one must remember that the question is not confined to environment, the word meaning nothing unless influence is delivered as well as exerted. That is to say, the picture is not complete unless the effect on or in self be measured as definitely as the influence directed toward self. In many cases one of the effects on or in self becomes a means of increased activity in some fraction of the non-self. For example, release of excess oxygen by diatoms may enable certain animals near them to release more carbon dioxide which enables the diatoms to release more oxygen.

Here we arrive at the problem of the wholeness of self or the boundaries between self and non-self. Even in the case of an individual man it seems obvious that the distinction is not sharp. For one thing there is the constant interchange of gases, a steady contribution of carbon dioxide to the non-self, a steady income of oxygen from it. At exactly what point does an atom of oxygen become self or an atom of carbon dioxide, non-self? Is it always safe to ignore this continuity in studying environment? How can such continuity receive proper recognition in a study of relationships?

Not only is self a fraction of the whole constituted by its self and non-self, but if it be an organism it is itself composed of fractions having recognizable importance in many problems of relationships. To mention a single example, there is the thyroid gland of higher animals which favors trends of relationships of specific type when in its so-called "normal condition," and which causes or permits wide divergences from this trend when injured or diseased. What is the possibility of finding quantitative expression for the influence of this and other fractions of self in establishing or continuing any observable set of relationships to non-self? If there be no possibility of quantitative expression what is to be our standard of values for qualitative expressions?

So far I have spoken of self and non-self with little attention to time, only a few vague references, in fact. But consideration of time is essential in any practice of examination of the relationships of self to non-self, especially when self is an organism. Furthermore, the part played by time in these relationships is not simple. First, there is the time of existence (age) of the self organism, the part which it takes in producing any combination of relationships is different in youth from what it is in maturity, and the responses to contact with particular fractions of environment are different in the two periods. Second, there is the duration of time of contact of particular fractions of non-self with the self, brief contact producing no observable result in cases similar to those in which remarkable results are observable after longer contact. Third, there is the time required for results to appear after exposure of self to certain influences of environment. Fourth, there is the rate of change (lapse of time between successive, observable changes) in relationships between self and non-self. How is time to be treated in discussion of all relationships? So far as I know, the only attempt to give quantitative designation to time in environmental studies is through use of divisions of calendar time. Since there is no true measure of time, might it not be more appropriate in some cases to use divisions of the cycles or rhythms of existence of selves in attempting quantitative expression of time? But, if that were undertaken, how should we establish a basis of determination of such divisions which might be intelligible to all of us?

So much by way of illustration of numerous abstractions in connection with questions of units of environment, which are too important to be ignored but also too elusive to be utilized in ordinary practice under present limitations of knowledge. I propose now to examine the question of units in aspects more closely related to ordinary usage. If one undertakes to study the ecology of an apple tree, he is likely to regard it as a unit surrounded by units of concrete type and by influences representing units of immaterial or distant type. In careless moments he may be speaking of a neighboring tree as a unit of environment at the same time that he speaks of temperature or air as a unit of environment. Again he may speak of a forest or of a valley as a unit of environment, meaning thereby that an aggregation of trees or an area of land is a part of or sample of environment which he intends to treat as a unit for particular purposes. If the single apple tree is the cause of mention of this particular list of features of environment he may give main attention to the effect of competition for soil by the neighboring tree, to certain extremes of temperature peculiar to the spot, to the humidity of the air, to the breeding of insect pests in the surrounding forests, and to the air drainage of the valley, thus indefinitely confusing influences with sources of influences, and comparing direct and positive influences with those of indirect, or diffuse, or highly composite character.

As I wish to give some time to the problems of mensural units I will not follow the preceding line of suggestions any further at present. Judging from my reading of articles on ecology it is generally assumed that degrees of temperature by either Fahrenheit or Centigrade scales are accurate measures of changes in influence of heat in the course of ecological investigations. Even if these measurements be satisfactory when used with proper precautions, allowances and reservations, it is probable that in ordinary usage they are not fully dependable and that they may be actually misleading. In the first place it is well known that organisms in nature are affected by other forms of radiant energy which accompany heat, but which are not measured, even light frequently going unmeasured in terms comparable with degrees. Furthermore, the fact that the degree of heat expended (or delivered to a certain spot) is not necessarily the degree of heat effective in any particular activity of the organisms is usually ignored. In addition, I rarely see any record of the energy relationships of heat accompanying the records of degrees. In discussing biological relationships none of these records have much value alone. Records of periods of duration and contact are often equally important. Confidence in the sufficiency of the mere record of intensity of heat by degrees appears to be most strongly shown by some of those experimenters who seek to maintain so-called "constant temperatures" in studies of organisms, a state of affairs radically different from that surrounding organisms in nature, and also radically different in the trains of relationship following its establishment in rigid contact with the organisms.

Evidences of the influence of temperature differ extremely with different organisms. I have seen buttercups blooming in the edges of snow banks amidst many other kinds of plants still dormant. This suggests the existence within the buttercup of a mechanism for a certain amount of control of temperature. If it exists in the buttercup, why not in other organisms? If it exists in any organism should it not be evaluated whenever the influence of change in heat intensities is discussed?

I am indebted to Dr. Burton E. Livingston for full realization of the fact that neither ecologists nor experimental biologists have any method of expressing the differences in influence between a ten-degree rise and a ten-degree fall in temperature, or of showing a whole series of differences in effects of fluctuations of temperature in relation to duration of periods of rise and fall. It is not uncommon, however, for observers to attempt to express the temperature relationship in terms of averages of degrees. It seems as though we should at least try to improve this situation. The problem of differences in the effects and evidences of effects in waxing and waning influences is not confined to temperature. It belongs to many other influences as well.

So, also, does the problem of lag in evidence of influence. I notice that some papers on ecology show commendable caution in respect to this point, but I am not so sure that others do. If a hot wind strikes a group of several different kinds of plants, some may show wilting or withering immediately, while others show little change for several days, although they may eventually perish. Perhaps all of us are willing to agree that the results of a particular influence may become distinguishable in widely differing periods of time, depending upon the age, vigor, activity, location and numerous other qualifications of the individual organisms, upon the intensity, amount, direction of contact, nature of contact, and duration of the influence, and upon the favorable or unfavorable trends of the concurrent actions of other influences. Therefore, it seems that we should not consider a record of temperature (or of any other measured influence) as being complete without attention to the possible lag between the recorded condition and its recognized result.

Assuming that what I have said about temperature may represent fairly well the more prominent things which I might say about other features of environment to which we attempt to apply some standard system of measurement, I will try a few suggestions regarding biological features of environment. One method of measurement of biological features rather commonly used is that of individual enumeration of organisms or aggregations of organisms, the size of the number serving to indicate the extent of the influence. Obviously, this method of measurement may be meaningless in many cases, *e.g.*, one of my little cassia seedlings was stripped of its leaves twice last summer, half a dozen big caterpillars doing most of the damage on each occasion. If six could strip it, the information that a dozen smaller caterpillars were also active would be misleading because destruction of foliage might have been complete without them. Furthermore, it is important to note that the big six were doing more damage than the whole eighteen on the first day after hatching from the eggs. Mere enumeration gives no clue to progressive changes in influence such as this. And when individual organisms are adopted as mensural units of influence it is necessary to limit comparison to other features of appropriate magnitude or else to establish a common basis of comparison. This is often impossible. A million plant lice may kill an apple tree which might also be killed by a single rabbit, but comparison of the lethal influences of the two types of organisms by enumeration would be very difficult. However, enumeration of individuals is the most nearly dependable of any method available for use in many studies of biological influences in or by populations.

So far as I know mass measurement of organic influences is mostly useful in handling problems of large magnitude (actually or theoretically), *e.g.*, the spread of a blight designated in acreage or the advance of an insect pest into new territory designated in miles or square miles. In my work I have not had much use for this method.

The measurement of influences of serums and toxins by effects of certain volumes, dilutions or concentrations on test organisms was regarded as a dependable method for a number of purposes a few years ago, but there is not so much confidence in it now if I understand the situation correctly. Still it has so great advantage for important types of work involving specific attention to interrelationships of particular organisms that it must be considered practical when properly used. However, so far as my information goes, no dependable mensural units exist for this method, the possibility of error in a given measurement existing in the origin of the substance, in the official test applied to a sample of it, and in its application. A poison derived from one animal or plant may differ in strength from that derived from a neighboring (not to mention distant) individual of the same kind. Of a group of organisms of the same kind used to test its strength one may be more susceptible than another and a given test organism may be more susceptible at one time than at another. Finally, the organism to which the poison is given may be highly susceptible while another of its kind is not, or there may be a difference in susceptibility in the treated individual according to time. A well-known example of difference in individual susceptibility is that in relation to bee sting, some men being indifferent to a single sting while others are made seriously ill by one.

Apparently there is no method of measuring a biological influence with an accuracy comparable to that of measuring heat intensity, and there appears to be even less possibility of measuring the relative effects of a biological influence and an influence such as heat when both are producing observable effects in the condition of an organism. Yet it must be evident that in many trains of circumstances subject to observation there are particular biological influences holding importance second to none.

I fear that my remarks so far have served mainly to qualify me for a position as a messenger of gloom so far as accuracy in quantitative terminology in discussing environmental relationships is concerned. But to offset this possibility I think it is only necessary to call attention to the large body of literature of ecology which has succeeded in conveying ideas of high practical value from one person or group of persons to another. Our savage ancestors succeeded in living effectively with few tools of very crude type, including language. They did the best that they could with what they had until they could get better, and I believe that is what we should do.

One point greatly in our favor is the strong tendency of environmental influences to flow steadily in definite channels guided by cyclical changes in our solar system. On this account many influences acting at fairly constant intensities keep a course approximately parallel, so enabling us to ignore them for many types of investigations. Thus we are relatively free to give our attention to influences of more irregular type, some of which we may choose to designate as dominating or determining, although their prominence is often dependent on one or more of those of regular type or on a preceding series of influences favorable to development of their prominence.

Whatever the impression received from my imperfect and rather superficial discussion of quantitative devices for handling ecological problems, I hope it will be clearly understood that I believe ecologists have had much commendable success in conveying ideas with very crude equipment, that we are making improvement in this equipment and the methods of using it, and that we can hope for still better results if we compare experiences and use them as a basis for concerted effort at further improvement.

THE RELATION OF MAMMALIAN DISTRIBUTION TO VEGETATION TYPES

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PLANTS are probably the most important feature in the environment of mammals, as well as of all other terrestrial animals. All mammals are dependent directly or indirectly upon plants for food. Plants also furnish to many mammals shelter from the weather, sites for homes, nesting material and protection from enemies.

Some animals are limited for food to particular species of plants, or perhaps to a few closely related species. This is true notably of some insects. A few kinds of mammals also are stated to be restricted closely in diet. The South American sloth is said by Beebe[1] to feed entirely on the leaves of the cecropia, and the Australian koala is reported[2] to be almost restricted to the leaves of the eucalyptus. Most mammals, however, can utilize a considerable variety of food species. Nevertheless, considerable preference is usually shown by each herbivorous species for particular plant foods, and when overpopulation occurs certain plant species may be almost extirpated over wide areas. When the preferred foods are exhausted the mammal usually is able to continue to live in the region by turning to other less palatable food plants.

While mammals are not usually restricted to particular plant species for food, they often do show a fairly close restriction to certain general types of plant food. There is always some restriction in diet, of which the difference between browsing and grazing mammals is an example. Forest animals are likely to be best adapted to the plant foods found in the forest; and prairie animals are likely to prefer the grasses and other prairie plants. The food relations of mammals may be said then to be in general with vegetation types, rather than with particular species or taxonomic groups of plants.

For homes and protection, also, mammals are usually dependent upon types of vegetation rather than upon particular species of plants. To the squirrel, which during part of the year makes its home in hollow trees, it makes little difference which kind of tree furnishes the hollow, but it is obvious that deciduous trees will supply more suitable nesting places than will conifers. Accordingly, the range of the eastern gray squirrel is found to be correlated in general with the distribution of deciduous forest.

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[1] William Beebe, *Bull. N. Y. Zool. Soc.*, 26, 13, 1923.

[2] F. E. Beddard, Cambridge Nat. Hist., 10, 148, 1902.

A great many factors are involved in the control of the distributional ranges of mammals, but, of these factors, vegetation is usually most important. The various factors, including the vegetational factors as well as the physical factors, are very complexly interrelated, and the distributional range of any species of mammal is the resultant of the interaction of all the environmental factors.

The physical factors of importance in determining the distribution of terrestrial mammals may be listed as physiography, soil and climate.

Physiography controls mammalian distribution chiefly through the modification of climate. It is well known that elevated regions have in general colder climates than regions with lower altitudes. The higher elevations also usually have more rainfall and a higher humidity, increased cloudiness and a greater intensity of light. Slope exposure to sun and prevailing winds also modify the climate considerably, the sheltered slope being usually cooler and having less evaporation than the exposed slope. Soil drainage and character are modified to a considerable extent by the physiography.

The soil affects mammalian distribution directly to some extent, chiefly because the character of the soil determines the ease of burrowing. The kangaroo rats, for instance, are weak burrowers, and are found chiefly in sandy soil. On the contrary, the pikas are found almost exclusively on rock slides, where they make their homes under the rocks. If the soil surface is covered with rocks the feet of fast-running mammals must have some protection by pads or hoofs. Soil drainage is an important item for the mammals, for in soils poorly drained the burrowing animals may be drowned out in periods of heavy rainfall. However, the soil affects mammal distribution mostly indirectly, through its influence on the distribution of the plants. The ability of the soil to absorb and to retain moisture are extremely important as governing the growth of plants; so also is the chemical content of the soil solution.

Of the factors of the physical environment climate is probably most important for the life of terrestrial mammals. Climate not only directly limits the distribution of some species of mammals, but indirectly, through its influence on the growth of vegetation, it affects the distribution of all terrestrial animals. Among the climatic factors involved in the control of plant and animal distribution are the various features of temperature, precipitation, air humidity, wind movement, evaporation and light. For each of these factors the extremes must be considered as well as the seasonal and the annual means.

The various species of plants and of animals require different sorts of environments, and the conditions under which one species will thrive may be wholly unfavorable for the existence of another related species. Examples in plenty are evident when any tropical biota is compared with the biota of a region of temperate climate in the same continent, or if a desert fauna and flora are compared with those of a nearby more humid area.

It should be noted that species are limited in distribution by different degrees of the same factor as well as by different factors. One species of plant may be limited in its northward distribution by the length of the growing season; another species by the line where killing frosts occur in winter. An extreme temperature occurring only once in ten years might well prevent the occurrence of a species in a region otherwise favorable for its existence. Further, all the climatic factors are interrelated, and a plant may be able to mature its seeds equally well in a region with short hot summers as in a region with long cool summers.

The animals, vertebrate and invertebrate, also constitute an important factor limiting the geographical distribution of animals and plants. The carnivorous species are of course dependent on the occurrence of their prey, and all species of animals must be in adjustment with the occurrence of their enemies and competitors. The incidence of diseases and parasites is also of much importance in controlling the distribution of both plants and animals.

The relationships between the various animals and plants of a region may be extremely complex. As already pointed out, some species of mammals are limited in distribution by the occurrence of their particular species of food plant or food plants, while most species are limited rather by the occurrence of vegetation types. The occurrence of some species of plants is prevented or their growth hindered by the presence of certain insects, and mammals also may seriously reduce the numbers of those plants preferred for food species. On the other hand, mammals may be beneficial to plants by eating injurious insects, by carnivorous mammals destroying herbivorous animals, and by the habits of some mammals which involve the transport or storage of seeds or vegetative parts of plants. Some of the species of animals and plants making up a biotic community will be affected adversely or favorably by the same grouping of environmental factors, others of the associated species will be controlled by quite other factor complexes. When we consider that the degree of abundance of every species affects more or less the existence of its food species, of its competitors, of its enemies and of its parasites, it is obvious that every species in an ecologic community is affected more or less directly by the activities of every other species. The physical factors of the environment are also directly involved, and any variation in an environmental factor affecting the prosperity of one species will affect ultimately and to some degree the whole community.

In this brief survey of the factors which limit the distribution of mammals and of plants it has been shown that plants limit the distribution of mammals in many ways, also that plants are limited in distribution by some of the same factors which limit the distribution of mammals. Although mammals are in general very adaptable, and although many forms range over several vegetation types, there is a considerable amount of correlation between mammalian distribution and types of vegetation.

In those cases where the occurrence of particular plant species does not directly or indirectly limit the distribution of mammals, the presence of certain plants might be considered to indicate conditions suitable for the presence of particular mammal communities. The use of plant species as indicators in this sense must, however, be applied with caution, because the habits of mammals apparently differ to some extent in different regions, and so also does the growth of plants. A mammal species closely limited in one region to occurrence in one plant community may not be so closely restricted throughout its whole range. Further, the plant indicators forming a major part of the normal environment at one location may appear elsewhere as scattered individuals, of little significance for mammalian distribution. In general the occurrence of vegetation and soil types are in my opinion better indices of mammalian distribution than are particular plant species. However, it will be freely admitted that many vegetation types are characterized over wide areas by particular plant species.

Our knowledge of the paleontological history of the various animal groups leads us to believe that changes in the specific characters of animals and plants, similar to those occurring in the past, are still taking place. We feel sure that slow but certain changes in the structures and reactions of many species are occurring, leading to the production of new varieties and new adaptations. Each new improvement or change in the characters of one species will affect directly or indirectly all its associates. Adjustments and changes in the distributional ranges of all species must continually be in progress.

The reaction of the animal to the environment is fully as important as the character of the environment in enabling the animal to exist. The animal reaction is in itself a most complex affair, and involves organs of perception, conductors of nerve impulses, coordinating nervous centers, regulatory mechanisms, all the organs of the body, and hormones and other complex biochemical compounds, all in a state of constant adjustment to external and internal changes. The process by which an animal selects the proper habitat or secures for itself the proper food must be amazingly complex, and we have so far made only the slightest beginning in attempting to unravel all the tangled threads involved in these reactions.

The few critical studies which have been made of the factors involved in habitat selection by mammals indicate that the selection is in at least some cases not controlled entirely by the physical factors of the environment. Two species of deer-mouse, which have very different habitats in the upper Mississippi Valley, one occurring in the forest and the other in prairie, I have found able to live and thrive in the same laboratory and under exactly the same laboratory conditions.[3] In this case it is evident that the habitat limitations are not due to any difference of temperature, air humidity or wind movement between the prairie and forest habitats, because at certain times of the day or at certain seasons the factors may be identical in the two habitats. As a possible indication of the solution of the problem it should be pointed out that mammals have a highly complex nervous system and often show a great amount of associative memory. I find no difficulty in believing that the basis of habitat selection in this case is an inherited tendency to react in a definite manner toward the visual and other stimuli associated with forest and prairie, respectively. Habit is almost certainly involved also. We can be quite certain that the selection is not based on a simple tropism of any kind.

It is the practice of plant ecologists to divide the world into a number of regional climaxes. The climax is the kind of vegetation which ultimately would cover the region if fires, denudation and the other destructive forces of the environment were absent. Inasmuch as each ecologic climax community presumably represents an extensive and old vegetation type it is logical to assume that each climax should contain at least a few characteristic animal species. The climax vegetation type should be and probably is a center of evolution.

Every field naturalist is familiar with the fact that there are some types of mammalian adaptation, both of structure and of behavior, which are characteristic of particular vegetation types. The mammals dependent on the forests have types of adaptation different from those dependent upon the grassland, and tundra animals could not survive in a tropical desert.

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[3] L. R. Dice, *Ecology*, 3, 47, 1922.

In every regional climax are found, in addition to the climax vegetation type, a number of ecologic communities which are successional stages leading toward the climax. Some of the successional stages in any given region may be very different in vegetation type from the climax, and will, therefore, constitute a very different environment for the mammals. Some of these successional communities are of quite constant occurrence and some cover extensive areas. From the standpoint of mammalian distribution the successional communities may be almost as important as the climax community. Although only of presumably brief life on any one spot certain of these communities may always be present in the province and form therefore important places for evolution and adaptation.

On the contrary, the smaller subdivisions of ecologic communities, as they have been outlined by the plant ecologists, seem to have only slight significance in defining the limits of mammalian distribution. It has already been pointed out that mammals in general are quite adaptable as to food species, and individual animals may wander over considerable distances. It seems logical to believe, therefore, that in a mixed forest a difference in the particular tree species dominating a particular spot might make relatively little difference to the mammals. Thus, the various pure stands or consociations or alternes of the same forest may contain the same aggregate of mammals. However, where a dominant tree species indicates a difference in environmental conditions that consociation may shelter distinct mammal faunas. This, for instance, is true of the yellow pine and Douglas fir alternes found on the slopes of Pike's Peak, Colorado. The yellow pine forest grows on the exposed mountain slopes, and it lacks some of the mammal species found in the more moist Douglas fir forest of the sheltered slopes. These alternes would, however, be considered distinct associations by some ecologists.

The smaller divisions of ecologic communities should perhaps be different for each major group of animals. The factors limiting the occurrence of a snail or an insect are probably different in part from the factors which limit the range of a mammal. Certainly the special habitats of some insects, such as those that live under the bark of trees, mean little to a mammal. Perhaps the smaller subdivisions of ecologic communities should be different for different kinds of mammals. For all I know this may be true of some of the plants also, for the factors limiting the distribution of fungi and of small herbs would seem likely to be at least somewhat different from the factors of importance to the forest trees. It is true that the forest in major degree makes the habitats for many of its inhabitants, but while the height and density of the forest cover are important environmental factors for the mammals, the precise tree species involved are probably of little consequence, so long as the quantity of available food and shelter is the same.

Some species and groups of mammals range over several vegetation types, and individual animals may move freely back and forth between several plant communities. A cottontail rabbit, for instance, might travel in the course of a night through several minor types of deciduous forest, through a meadow, and into a blackberry patch. When we consider that a large mammal can and often does travel across a number of ecologic habitats within the space of a few minutes it seems useless to try to apply the minor ecologic subdivisions to these animals.

The mice and shrews and other small mammals have smaller individual ranges than do the larger species, and these smaller species are somewhat more restricted in habitat than are the larger forms. However, even the smaller species of mammals show little evidence of limitation to minor plant communities, but are in general related in distribution mostly to soil types or vegetation types.

Stratification or layering is sometimes conspicuous in mammalian communities. In a forest, for instance, the fossorial, ground-living and arboreal types of mammals may be quite distinct. However, the same individual animal may move frequently from one layer to another.

The best method of classifying the distribution both of vegetation and of mammals and other animals seems to me to be a division of the continents into biotic provinces, each of which is made up of several ecologic communities. At one time I called these districts biotic areas,[4] but Vestal's term of biotic province[5] has priority and is better. Each biotic province is characterized by its climax community, but the climax community of one biotic province often may be found as a minor or successional community in adjacent provinces. There are also communities which do not reach dominance in any biotic province, and some of these communities, such as the semi-aquatic communities, may have a wide distribution in several provinces.

The classification of the data of biogeography according to biotic provinces and ecologic communities will point out, I believe, the relationships which exist between the distribution of animals and plants, and also will show to some extent the relationships which both plants and animals have to climatic and physiographic provinces, soil types and the past history of each region.

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[4] *Science*, n. s., 55, 335–338, 1922.

[5] *Amer. Nat.*, 48, 432, 1914.

BRIGHTER DAYS AHEAD

By **RALPH E. DANFORTH**
WEST BOYLSTON, MASSACHUSETTS

We often hear it stated that one twentieth of the world's population will be able to grow the food for the world. Perhaps machinery and methods will be such that less than one twentieth will be able to do it. Perfection of methods and machinery to do the work formerly done by many men and women will reduce the number of workers in manufacturing, commerce and salesmanship as well as in agriculture. What then will the great bulk of the population do? Will the above varieties of work be done by a few, or will the many divide it up, doing each a little of it daily, and having most of the day free for intellectual, artistic, musical and scientific activities, not to mention pure recreation?

The relations of labor and capital may seem like a different question but really it bears very directly upon the question above. It is doubtful that the workman will ever be content unless he (1) devotes part of his day to intellectual and esthetic pursuits, and (2) is not only a laborer but also partly a capitalist. When the workman is both capitalist and of the intelligentsia then the most serious problems between capital and labor will be solved. No real man or woman with active human brain will ever be satisfied to toil all day or most of the day as a wage earner working for others. He craves to devise his own life, think his own thoughts and fill his own place in the social world and the great world of outdoors.

Labor will not feel that it receives its full share of the earnings of industry however much of these it may be *given*. But if laborers labor but a few hours a day and live the higher life most of the day, exercising head and heart to the full, and enter into financial responsibilities they will feel that their labor is salubrious exercise without which they would not be as healthy or as happy, whereas their real life and much of their support came from other sources.

It is both humorous and pitiful to see a capitalist or other intellectual struggling to exercise his body enough to keep it trim and strong. How he toils at the setting-up exercises or in the gymnasium or on the golf-links when he can not take the time to go to the wilderness to hunt, fish or climb mountains. How eagerly he looks forward to a real expedition through less-known portions of the world! It would do him good to join the workers for a short time daily, and he would accomplish more, not less, of his intellectual work for doing it. Then would be established the true democracy of feeling which would break down the tension between the classes, yet never destroy the real difference between capable and incapable, wise man and fool. The individual would be forced to realize that it was his own fault or due to some insufficiency on his own part if he did not do as well as the other man.

Without any socialistic division of property the worker, working but a few hours a day, which would be all his share of the work needed by the world in which machinery and methods and power were doing most of the labor, would have most of his day free to use whatever mind and heart he possessed or could develop. He would have as good a chance as any one else to become a capitalist, a writer, an artist or musician.

The amount of capital invested in agriculture, manufacture, commerce and trade will perhaps increase as the required labor in the various fields of activity diminishes. There will be place for every laborer to invest what capital he can command. Thus capital rather than labor will increasingly direct the world's industry, while every truly intelligent laborer should be able to become, in part at least, a capitalist.

No human being is well rounded out unless he has developed what musical, artistic, literary, scientific and social capacities may be latent within him. He will not be happy or contented until he tries to do it. The short day and possibly the short wage, which may in future be unavoidable, may be the means of developing all those who are truly "worth their salt." If he is also a capitalist he will have no cause to complain, he will not suffer. His labor will bring in a part of his living and his other activities will bring in the rest. He will get his share of the other profits of industry because he will have bought diversified investments in industry. He will own as large a share of the capital of industry as he has the intelligence to secure honestly. He will not be prevented from doing this by being forced to labor long hours, in perhaps unhealthful circumstances, under the nervous strain of a mind not finding adequate outlet for its capabilities and under possibly undue physical strain.

Some one may ask right here how a person starting on part time could become a capitalist. One may reply that various individuals have started with nothing and become wealthy; that we do not expect the general public to become wealthy, but comfortable and happy; that individuals fit only to be coddled in a charitable institution could hardly expect to become capitalists or even independently comfortable and happy.

Far less than one twentieth of the world's population devotes time to scientific research, yet the number of those doing this research is rapidly increasing and the research workers are being increasingly well paid. As the demand for labor diminishes the demand for research will increase, so will the demand for literature of high grade and the demand for real art and music. Love of nature and the outdoor life in free sunshine, pure air, clean water to swim in, trees and parks and birds and mountains to enjoy, love for all these will increase.

The world has to-day many unfortunate individuals who should never have been born. No social or economic system can cure their fundamental troubles or give them their share of this world's goods. That would be asking too much of any plan for human betterment. Brighter days can exist for them only when they cease to exist. Perhaps a part of the scientific research may be directed to prevent such from being born into the world. Brighter days are ahead.

The present unemployment has been attributed variously to the world war, overproduction, tariff barriers, speculation, increased mechanization of industry and numerous other causes. The increased mechanization of industry will help to bring brighter days to the public in general, emancipating from drudgery, increasing leisure and adding to the general wealth of the world.

But the brightest days ahead are for the brightest people and the best. Pride of family will make those with the finest bodies and keenest minds and purest morals and noblest hearts increasingly careful to keep their families up to their high standards and even to improve thereon. The youth of such families, led both by family pride and by a selective love for the very best in man as in all else, will be able to "fall in love" only with those most lovable and worthy to join their truly superior family circle. Here again scientific research will come to their aid, showing them more clearly what desirable and what undesirable traits are in the hereditary make-up of any likely person.

Brighter days are coming to all, but not to all equally, for all are not equal.

I can not believe, as some seem inclined, that war, sex and alcohol will always continue to be the great playthings of man. His brighter days and more fortunate circumstances will help him to become too intelligent to continue to consider any one of the three as playthings. Each will be relegated in time to its proper place, war to oblivion, sex to the production of better and ever better men, alcohol to strictly industrial uses. Drugs, including narcotics, will be more truly evaluated and used where, when and as they may confer the greatest real benefit.

The reign of common sense which should accompany the mechanization of industry will not eclipse the joys of living but increase them, both in number and quality. More and stronger joys will thrill the better life men will be living in the brighter days to come.

In the brighter days ahead, man's faith in his fellow man will increase because it will be better founded. There will be more reason to believe in your neighbor. You yourself will be more worthy of confidence.

THE WAYS OF THE ALLIGATOR

By Professor **ALBERT M. REESE**

PROFESSOR OF ZOOLOGY, WEST VIRGINIA UNIVERSITY

ONE who is known to be interested in the Crocodilia must be prepared to answer frequently the question: What is the difference between an alligator and a crocodile? While several distinctions may be given, it usually suffices to say that the snout of the alligator is wider and more rounded, and that the fourth mandibular tooth on each side fits into a corresponding pit in the upper jaw, while in the crocodile this enlarged tooth fits into a notch in its corresponding upper jaw. There are also differences in habits and temperament, as will be noted later. The genus Caiman is quite similar to 'the alligator and is often called alligator in the regions it inhabits.

Of the two species of alligator only the American will be discussed; the other form lives in China and the writer has no first-hand information concerning it.

It is possible that the word *alligator* is derived from *el lagarto*, the lizard, since it would have been very natural for the early Spanish settlers to call these similarly shaped animals lizards.

The American species, *Alligator mississippiensis*, is found in the South Atlantic and Gulf states from North Carolina to the Rio Grande. Kellogg reports isolated cases of alligators being found in New Jersey. The writer once investigated the report of an alligator living at Richwood, West Virginia. The animal, it seems, lived in the log pond of a saw mill at that place. It had been brought by a returning tourist from Florida and had been protected during the cold winters by an exhaust pipe from the mill that kept an area of warm water

FIG. 1. BUNGALOW OF THE TROPICAL RESEARCH STATION IN BRITISH GUIANA

FIG. 2. A TYPICAL SCENE IN THE OKEFINOKEE

in the pond in which it lived. It may be that the New Jersey alligators reached that unusual latitude in a similar way.

The alligator is quite sensitive to cold and in its natural habitat may pass the colder portion of the year in its cave or buried in the mud. In northern latitudes, even when kept in a fairly warm room, it will often lie more or less dormant and refuse all food for several months of the colder part of the year.

Being of amphibious habits it spends most of its time in or near water, but it may wander from pond to pond over considerable stretches of dry land.

If the accounts of early travelers are to be believed, the alligator was once to be found in incredible numbers in many of the southern watercourses. Bartram says:

> The rivers at this place from shore to shore, and perhaps near a half mile above and below me, appeared to be one solid bank of fish of

various kinds, pushing through the narrow pass of San Juans into the little lake on their return down the river, and the alligators were in such incredible numbers, and so close together from shore to shore, that it would have been easy to have walked across their heads, had the animals been harmless.

There were in those days, too, it was said, monsters measuring twenty feet or more in length. But the gun of the hide hunter and the rifle of the sportsman have changed all this, and no such numbers are now to be found and seldom is an animal seen that measures more than twelve feet.

It is not likely that the species will be entirely exterminated in the near future, since there are many inaccessible retreats in which it can hide and there are one or two preserves and numerous farms where, for one reason or another, the animal is protected. In some restricted sections the alligator is protected by law during certain seasons.

It is quite customary where a large alligator is on exhibition to tell visitors that the animal is "probably more than a hundred years old." It is likely that there is not the slightest foundation for this statement. Specimens have apparently lived in captivity for thirty or forty years. How any authentic information in regard to a wild specimen could be obtained is hard to imagine.

It was found in the Bronx Zoological Park that well-fed alligators grow at the rate of about one foot a year for the first ten years, after which the growth is slower, so that a fifteen-foot animal is probably much more than fifteen years old. Sexual maturity is probably attained in six or eight years.

The alligator, though apparently sluggish and awkward, is well adapted to its environment. Its rough, scaly back not only protects it against attack, but makes it highly inconspicuous as it lies quietly in the water or on a grassy bank (Fig. 4). As it floats or swims at the surface of the water, its eyes and nostrils are the only parts that project above the surface; by allowing something less than a foot for each inch between these two exposed spots the total length of the animal may be estimated.

When alarmed, the animal if in the water may sink quietly to the bottom, or if on the bank plunge in and thus escape. Parker found that the animal may remain submerged for more than five hours before drowning.

The tail, which is compressed and has a distinct fin along most of its dorsal side, is an excellent propeller that enables the animal to swim with sufficient speed easily to keep ahead of a rowboat

FIG. 3. A. M. NICHOLSON, A FLORIDA GUIDE

PICKING UP A DIAMOND RATTLER, A NEIGHBOR OF THE FLORIDA ALLIGATOR.

FIG. 4. AN EIGHT-FOOT ALLIGATOR
JUST DRAGGED FROM ITS HOLE.

FIG. 5. A GUIDE OF THE OKEFINOKEE SWAMP

or canoe. When swimming rapidly, the legs are held close against the sides of the animal so as to offer as little resistance to the water as possible. On land the tail may serve as a very effective weapon of offense or defense. Kellogg reports from Sweet "that a supposedly dead alligator nine or ten feet in length once snapped its tail against a man weighing two hundred pounds, breaking one of the victim's legs and throwing him several feet. The man was picked up unconscious." According to Ditmars the crocodile is more apt to act in this unpleasant manner than the alligator. He thus describes an experience of his own:

FIG. 6. "ALLIGATOR JOE"
A GUIDE OF THE EVERGLADES, IN HIS DUGOUT CANOE.

> The writer well remembers his first acquaintance with a big fellow from Florida. Driven out of the crate the crocodile looked the picture of good nature. Standing away from what he thought to be the reach of his tail, the writer prodded the apparently sluggish brute with a stick to start it for the tank. Several things happened in quick order. With a crescentic twist of the body utterly beyond the power of an alligator, the brute dashed its tail at the writer, landing him such a powerful blow that he was lifted completely from the ground. As he left terra firma, an almost involuntary inclination caused him to hurl his body away from a pair of widely gaping, tooth-studded jaws swinging perilously near. Landing with a thud on one shoulder, though otherwise unhurt, the writer threw himself over and over, rolling from the dangerous brute that was actually pursuing him on the run, body raised high from the ground. For an instant it seemed as if the crocodile would win. As the writer sprang to his feet and glanced backward, he beheld the brute throw itself flat on its belly, open the jaws widely, then remain motionless as a statue. Such is the average crocodile—an active, vicious and, above all, treacherous brute.

Ditmars says again, in the same book:

> When the keepers of the reptile house of the New York Zoological Park clean out the big pool of the crocodilians, they actually walk over the backs of some of the big gators, so tame are these. They never become unduly familiar with the crocodiles, finding it necessary to pen the latter behind heavily barred gates—and in

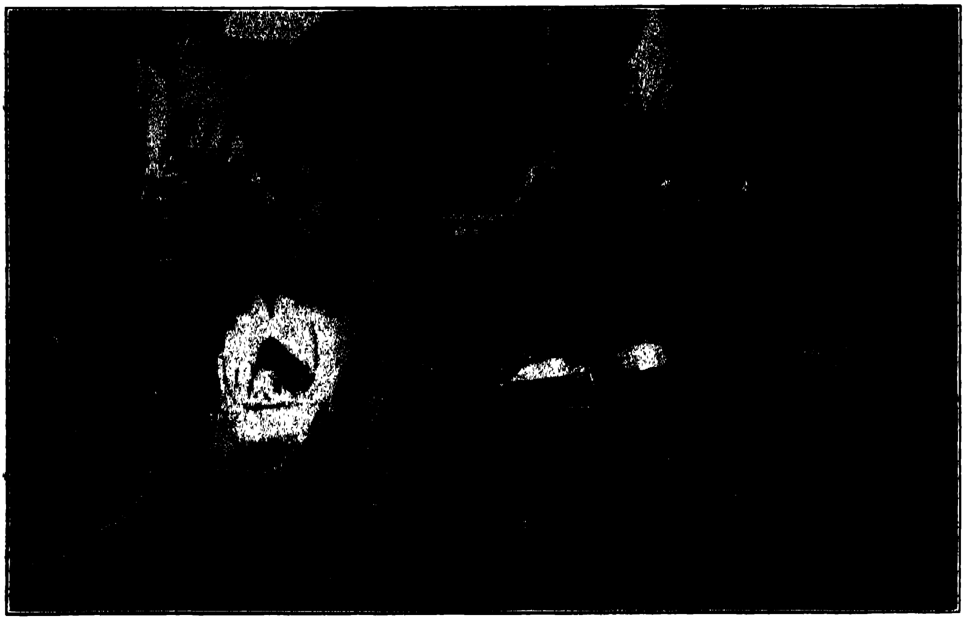


FIG. 7. INTERIOR OF THE MOUTH OF AN ALLIGATOR SHOWING THE TRANSVERSE LINGUAL AND PALATAL FOLDS THAT SEPARATE THE FRONT REGION OF THE MOUTH FROM THE PHARYNX.

the process the men are often chased from the enclosure.

The tail is probably used also when the alligator seizes a large land animal and drags it under water to drown. This may be illustrated by feeding a tough piece of meat to two small alligators at the same time. As soon as the meat is seized each animal presses his legs close to his body and, by means of his tail, whirls over and over until the meat is twisted in two or one animal loses his grip on it. A large alligator by this means would be able to drown almost any ordinary land animal. Although so sluggish most of the time, the alligator is capable of almost lightning-like motions of its jaws in snapping sidewise at a moving object.

One of the curious ideas concerning Crocodilia is that it is the upper, not the lower jaw that moves. It is obvious that when an animal is lying with its head flat on the ground and opens its mouth the upper jaw must be lifted since the lower jaw can not be lowered.

To permit the alligator to hold a struggling animal in its jaws or to chew it, while submerged, without getting water into the trachea, it is provided with two folds of skin across the back of the mouth, one from the top of the base of the tongue, the other from the roof of the mouth (Fig. 7). When these folds of skin meet they form a water-tight partition that prevents water in the partly open mouth from entering the pharynx where the glottis, the opening of the windpipe, is located.

Unlike most of the class Reptilia, the alligator has a voice, and the strange bellowing of an old bull may be heard for perhaps a mile. Whether this voice be a call to females or a challenge to combat with other males is difficult to say. The young alligator makes a curious grunting noise that, with a little practice, is easily imitated, and it is customary for hunters to make this noise, with the idea of bringing the submerged adult animals to the surface where they may be shot. With its ear valves tightly closed and with several feet of water above it is difficult to imagine an alligator hearing this comparatively faint sound. As a matter of fact the writer never saw a hunter get any response to his grunting.

Even before emerging from the shell the alligator makes a sort of squeaking sound that may be heard for some yards; the use of this vocal effort will be mentioned later.

Captive alligators, even those of smallest size, often expand their bodies with air which is then expelled with a hissing sound that, in the case of a large animal, seems quite threatening.

Another characteristic, said to be more evident during the mating season, is musk, extruded from two pairs of glands, one pair under the skin of the lower jaw, the other pair opening into the cloaca.

The food of the alligator consists of practically any kind of animal matter, including its own kind, and even a certain amount of vegetable food may be consumed.

Kellogg has recently studied the feeding habits of the alligator, chiefly by examination of the stomach contents. He says: "The food of the alligator is made up chiefly of crustaceans (47 per cent.), fishes, turtles and other vertebrates (29 per cent.) and insects and spiders (23 per cent.)." It does not appear that they are seriously destructive of useful forms of wild life, as muskrats and turtles, and important food fishes do not bulk large in their diet. Their depredations on crabs and shrimps are not sufficient at present to cause fishermen any difficulty in meeting the market requirements. The insects they consume mostly are economically unimportant, and any influence they may have on the control of objectionable species of animals and plants is for the most part negligible. They undoubtedly are beneficial, how-

FIG. 8. "PROFESSOR" PYLE

A SOUTH AMERICAN GUIDE OF ETHIOPIAN EXTRACTION, AT THE EDGE OF A GATOR HOLE.

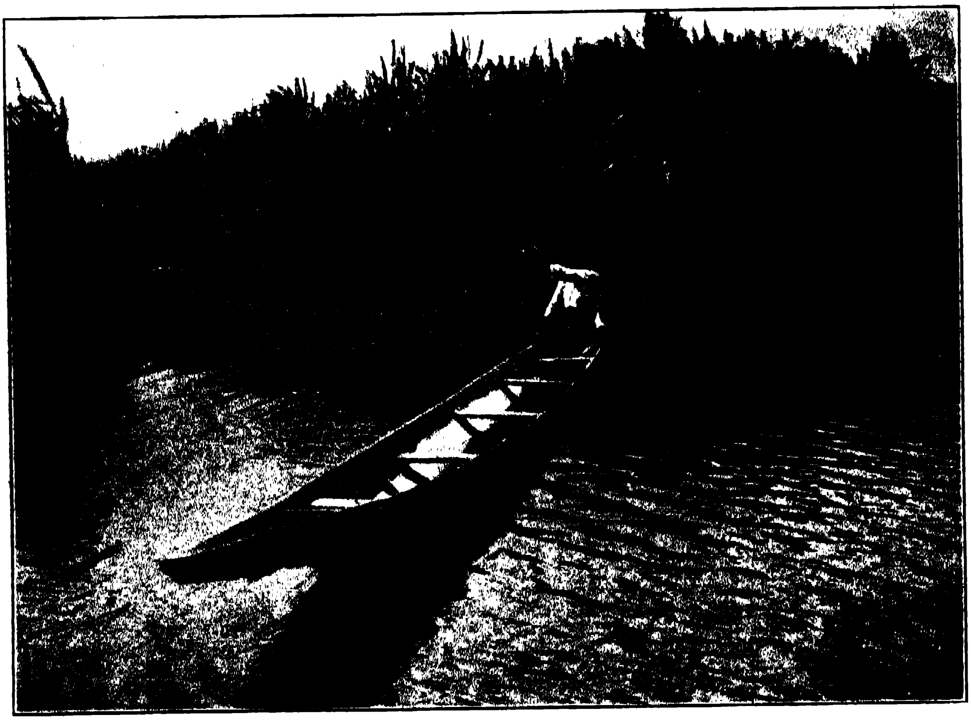


FIG. 9. PERONG
AN EAST-INDIAN GUIDE OF BRITISH GUIANA, IN HIS DUGOUT CANOE.

FIG. 10. ALLIGATOR HUNTERS OF THE OKEFINOKEE SWAMP

ever, in feeding upon the voracious alligator-gars, which destroy food fishes, and upon crawfishes, which are burrowing pests of agriculture.

In captivity the alligator will eat readily any kind of raw meat, including mice, rats or other animals of suitable size. To demonstrate "crocodile tears" it is only necessary to feed a hungry gator with a piece of meat just a little too large to be swallowed whole. While straining to gulp down the overlarge mouthful, tears will be squeezed from the animal's eyes in a very amusing way.

What the swallowing capacity of a huge alligator might be, it is difficult to say, but Ditmars thus describes the fate of a dog that approached too near a large specimen:

> As a dog, weighing about fifty pounds, unwarily approached the creature's tank, it was suddenly grasped and before completing its first yelp of terror was dragged beneath the surface. A few minutes later the twelve-foot saurian appeared at the top, holding the dead canine in its jaws. The dog was shifted about, amid the sound of breaking bones, and swallowed head first, and entire, after a few gulps.

The economic importance of the alligator is of course chiefly in connection with the use of its skin in making leather, though there is a considerable sale of young animals and of various alligator novelties to the tourist trade.

In 1902 the annual output from the tanneries of the United States was about 280,000 skins. During the past few years, according to Kellogg, the total number of hides taken in the United States would scarcely exceed 50,000 a year.

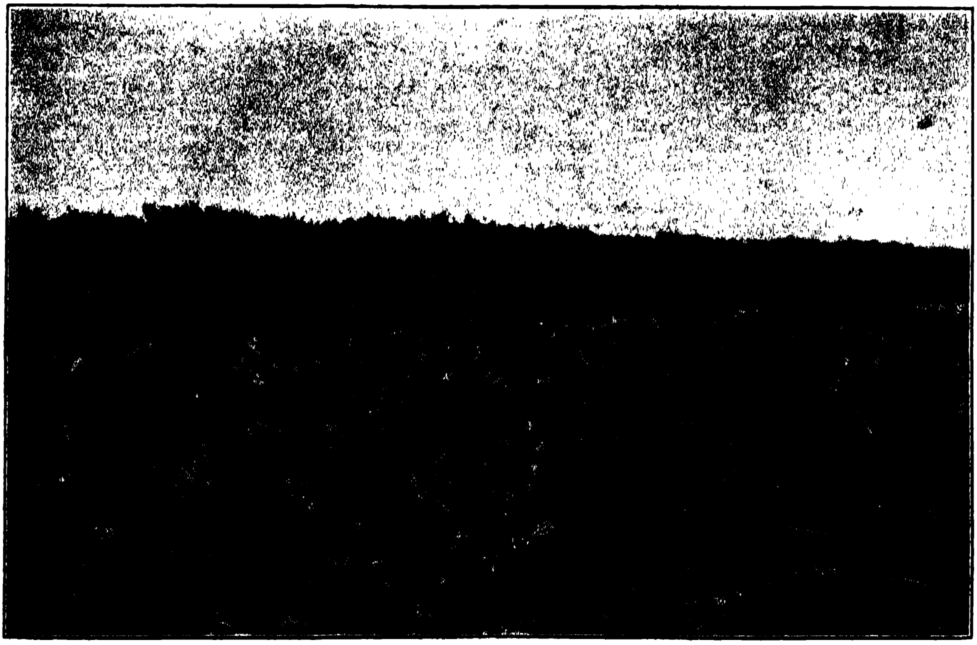


FIG. 11. JACKSON SLOUGH, FLORIDA

FROM THIS POND NUMEROUS ALLIGATOR TRAILS LED TO HOLES SUCH AS SHOWN IN FIG. 17.

In hunting alligators two methods are generally used. The more common way is to go after them at night, generally two men together in a small boat. The man in the stern propels the boat, either with a paddle or with a pushing pole. The man in the bow is provided with some sort of light, such as an acetylene

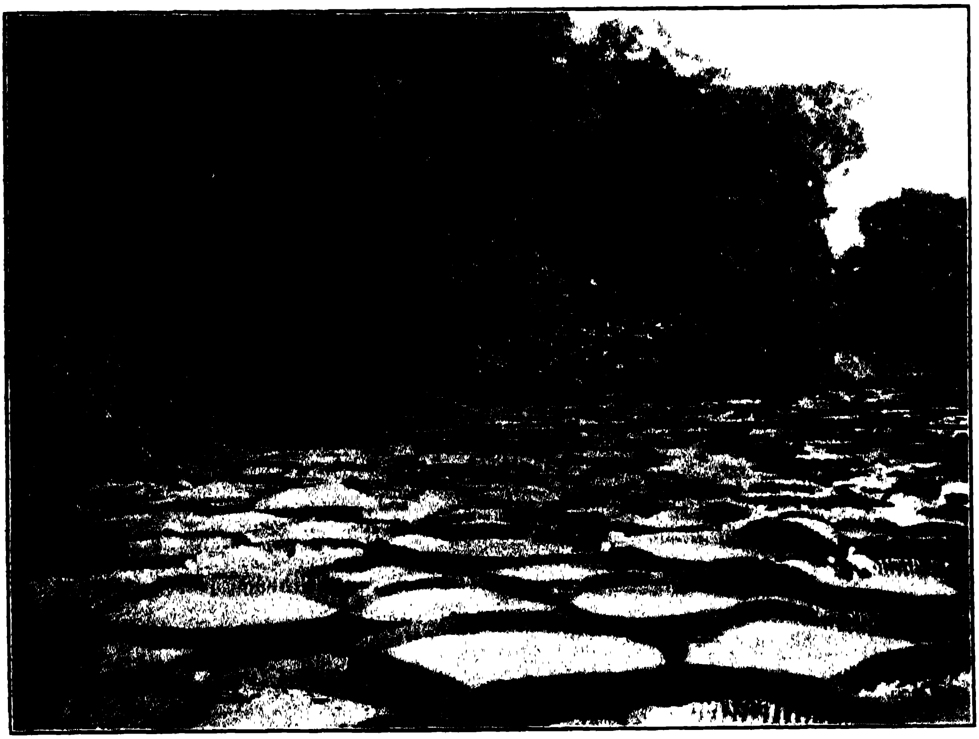


FIG. 12. A SOUTH AMERICAN GATOR POND
COVERED WITH VICTORIA REGIA LILY PADS

lamp like those that miners wear in their hats. This light causes the eyes of the alligator to shine in the dark so that they may be seen for many yards. The boat is paddled to within easy range and the whole top of the gator's head is blown off with a shot-gun. The dead animal is thrown upon the bank, to be collected and skinned the next day. A rifle may be used instead of a shotgun if the hunter be a sufficiently good shot to hit the eye of the gator.

It is commonly supposed that the animal is shot in the eye because the bullet will not penetrate the skull at any other place. This of course is absurd. But if the head of an alligator be examined, it will be found that a bullet entering the skull through the eye, especially from in front, is almost sure to go through the brain; a dozen holes might be shot through the skull in other regions without hitting the very small brain or causing a fatal wound. Another reason for shooting at the eye at night is that it is the only part of the animal that can be seen.

The other common method of capturing the alligator is to prod him, as he lies in his cave, with a long pole on the end of which a large hook is fastened; when he seizes the hook he is pulled out —not an easy undertaking if the animal be a fairly large one. It taxed the combined strength of the writer and a guide to the limit to drag an eight-foot gator from its hole.

The writer has never been in the alligator country during the mating season, but it is said that the bellowing, mentioned above, is much more frequent and that the air is often tainted with musk at this time. That there are also fierce combats waged seems likely from the mutilated or missing appendages that are frequently noticed. After the mating season the nest is built and the eggs are laid.

In order to know when to get to Florida at a time the eggs were being laid, numerous return postals were addressed to "The Postmaster" at certain places located, so far as could be told by examination of a map, on streams and other bodies of water. These postals asked at what time of year alligators laid their eggs. According to the return cards, the laying season extended through practically the entire year. This illustrates how unreliable information may be though obtained from people who might be expected to know the facts.

It was later learned from Dr. S. F. Clark, who was a pioneer in the study of the Florida alligator, that the egg-laying season is in June. The first eggs were found on June 8; the latest to be laid were on June 26. In British Guiana, the cayman's egg-laying season was a few weeks earlier, but there was not so much difference as might be expected between localities at 7° and 25° north latitude.

On one expedition numerous nests were found, but none contained eggs. When the first rain came, to end a rather prolonged drought, every nest was found, the next morning, to contain eggs. It was evident that the female alligator was waiting for a rain to dampen the nest before she deposited her eggs in it.

It is supposed that the female alligator builds the nest, though there is probably no definite proof that the male does not do his share of the home building. As a matter of fact, the secondary sexual characters are so slightly developed, if at all, that it is practically impossible to distinguish the sexes by superficial appearance. At any rate, the nest consists of a rounded or conical pile of vegetable matter, the material of which depends

FIG. 13. A TYPICAL NEST OF THE FLORIDA ALLIGATOR

FIG. 14. A SMALL NEST OF THE CAYMAN

MADE ALMOST ENTIRELY OF GRASS AND EXPOSED TO THE FULL FORCE OF THE TROPICAL SUN

FIG. 15. AN ALLIGATOR'S NEST

OPENED TO SHOW THE IRREGULAR PILE OF EGGS upon the character of the vegetation at the place where the nest is located. Fig. 14 shows a nest made almost entirely of saw-grass; Fig. 15 is a nest composed of flags and other similar plants; some cayman nests were made of fine débris scraped together into a mound; some crocodiles bury their eggs in sand. After piling up the material into a nest the animal apparently crawls over it, as indicated by the tracks, probably to make it more compact. The size of the nest varies from perhaps a small wheelbarrow load to a large cart load, and, as said above, it may be high and conical or very low and flat. After some weeks it may become so baked and hard on the surface that it can not well be torn open with the bare hands, and one nest was so compact that when the writer stood on it, thinking it was an old and unused one, only two or three of the forty-eight eggs contained in it were broken.

After the nest has been built, compacted and rained upon, the female opens a hole in the top and lays the eggs, with no noticeable arrangement, in the center of the mass of vegetation; she then covers them over so well that it is not possible without opening the nest or feeling in it (Fig. 15) to tell whether there are eggs in it or not. Often a nest that was torn open and found empty was covered over again by the alligator the next night, though she perhaps laid no eggs in it.

Many tales are told of the dangers of robbing an alligator's nest; so far as the writer's experience goes there is not a word of truth in these reports.

The nest is usually built on a slight elevation not far from the alligator's cave. It may be completely exposed to the sun or it may be in comparatively dense shade.

The number of eggs seems to bear no relation to the size of the nest. In a rather small nest forty-eight eggs were found, the largest number found in any one nest; in other nests less than a dozen eggs might be found; the average number per nest was about thirty. As many as sixty eggs have been reported from a single gator's nest, and one hundred eggs have been claimed for one crocodile's nest.

The eggs of the alligator vary considerably in size in different nests and somewhat in the same nest; the average diameters of a large number of eggs measured were approximately 73.5 mm and 42.5 mm.

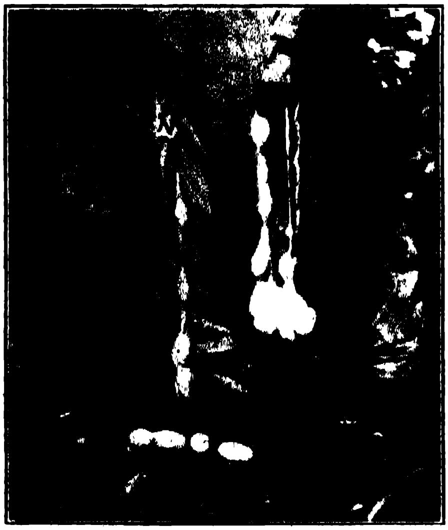


Fig. 16. OVIDUCTS AND EGGS OF FLORIDA ALLIGATOR

The eggs are almost invariably perfect ellipses, not smaller at one end as in the case of the hen's egg. There is a thick, calcareous shell, rather rough in the alligator and in the cayman sometimes as rough as fairly coarse sandpaper. When first laid the shell is pure white, but it often becomes stained by the damp material of the nest.

An egg that has been incubating for some time may usually be recognized by a chalky band, perhaps a couple of centimeters wide, that extends around the center of the smaller circumference.

FIG. 17. A SMALL ALLIGATOR HOLE IN FLORIDA

This band is caused by a chalky deposit in the shell membranes, as may easily be seen by removal of the shell.

The yolk does not appreciably differ from that of birds' eggs, but the albumen, especially in the cayman, is distinctly green and of such thick consistency that the entire contents of the shell may be poured out into the hand without greatly changing its shape. One who has removed for study the blastoderm of a chick will remember that the operation is by no means easy; the removal of the alligator's blastoderm, if one be fortunate enough to find an unincubated egg, or even of an early embryo, is considerably more difficult.

The chief object in hunting alligators being to obtain their eggs for embryological research, it was of course important to obtain the eggs at the beginning of their incubation. Various empty nests were found and were visited several times a day, in the thought that if the eggs were obtained a few hours after being laid they would be practically undeveloped. Such, alas, was not the case, for newly laid eggs contained embryos of the stage of a thirty-six or forty-eight hour chick. Eggs removed from the oviducts of a just-killed alligator (Fig. 16) sometimes contained well-formed embryos, and the few unincubated eggs that were thus obtained refused to develop, though apparently fertile. The only way that Voeltzkow was able to make the eggs of the Madagascar crocodile develop, in these beginning stages, was to remove them, at certain intervals, from the oviducts of a captive living animal. After the embryo is well formed, the egg may be transported indefinite distances without interrupting the course of incubation. On leaving South America some years ago the author packed two or three cayman eggs in a small basket of vegetation from the nest, and put them in his trunk. The trunk was not opened during the voyage of about two weeks, but when it was unpacked in Maryland, out crawled a baby cayman, perhaps the first of his kind to be born in a steamer trunk.

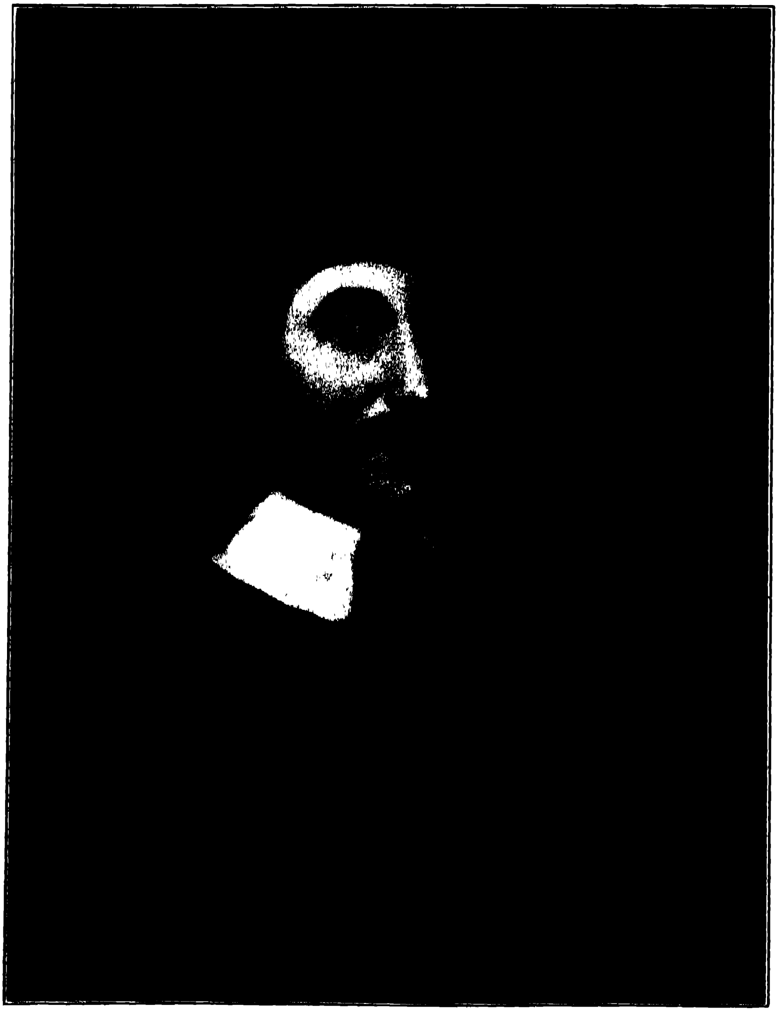
The alligator is about eight inches long when hatched, and it would seem perfectly impossible for so large an animal to have been contained in so small a shell, until one notices how much of the length of the new-born animal is in its tail and how compressed the tail is; it is a very snug fit at any rate.

It was formerly said that the heat of the sun caused the incubation of the alligator egg. Others now say it is the heat of decomposition of the green vegetable matter of which the nest is built that causes incubation. The writer is convinced for various reasons that neither of these ideas is correct. Many nests are built where they are exposed to the full strength of the sun all day; other nests, especially of the cayman, were found in the dense shade. When the hand is pushed into the center of a nest it feels distinctly cool during the heat of the day and distinctly warm during the night and early morning hours when the air temperature is possibly fifty degrees cooler than at mid-day. At all times the interior of the nest is moist. In other words, the compact mass of green vegetation simply serves to keep the egg moist and at a fairly even temperature. A "setting," if it may be so called, of alligator eggs continued the process of incubation in a perfectly normal way when packed in a box of wet sawdust that was kept in the sun in a Baltimore backyard during the day and was covered with blankets at night. The temperature of the interior of the mass of sawdust was found to stay fairly constantly at about 80° F. Alligator eggs were also incubated readily in an ordinary incubator at about 95° F.

It is an interesting illustration of the variability of living things that while the alligator egg develops in a moist nest and will probably die if allowed to dry, the Madagascar crocodile egg, which is almost exactly like the alligator egg, according to Voeltzkow, will mold and die if *not* kept dry.

The period of incubation of the egg of the Florida alligator is probably between eight and ten weeks and probably varies with the surrounding conditions.

As has been said, the young alligator may make a squeaking noise for some hours before leaving the shell, and it is supposed that the mother, whose cave is generally nearby, hears the cry of her new-born or about-to-be-born infant and comes to its rescue, otherwise it is hard to believe that it could dig its own way out of the compact and often sun-baked nest.



JOHN WINTHROP, JR.

THE ROYAL SOCIETY OF LONDON AND ITS INFLUENCE UPON SCIENTIFIC THOUGHT IN THE AMERICAN COLONIES[1]

By FREDERICK E. BRASCH

CHIEF OF SMITHSONIAN DIVISION, LIBRARY OF CONGRESS

THERE is nothing that has contributed so largely to the rapid progress which science has made since the Renaissance of learning in Western Europe as the growth of scientific societies and academies. To Italy, during the revival of learning, belongs the honor of being the first home of these modern organized academies, with the Accademia dei Lincei in Rome, founded in 1603. England was not slow in following the example of this enlightened spirit. Scientific truth was asserting itself in isolated places and by individual efforts through observations and experimentations contrary to the current tendencies in philosophy and religious dogma. Copernicus and Brahe led the way by observation, Galileo by experimentation, followed by Kepler and Descartes and Newton on mathematical analysis; Gilbert, Harvey and others, each in his turn laid the firm foundation of the value of empirical truths as derived from the phenomena of nature. In concentrated centers of learning of the early Renaissance, such as Oxford and Cambridge, the Aristotelian metaphysics of interpreting these phenomena predominated to the exclusion of the modern methods of experimentation or empirical truths. Scholasticism had prevailed so long that its firm hold in these centers of learning made it dangerous doctrine, if not possible heresy, to accept truths of nature derived by experiments and observational means. The basic principles of the current philosophy in England was that which was promulgated by two English philosophers, Bacon and Hobbs. What Bacon advanced was a method new to science, reasoning from particulars to higher generalities. Hobbs advanced what Bacon overlooked, namely, the deductive method. Both methods have their function in scientific progress.

It was this philosophy that led the early scholars of seventeenth century England to follow in the footsteps of the masters in the new method, namely, Copernicus, Galileo, etc. Therefore, the Royal Society of London was organized for the express purpose of advancing experimental knowledge and interpreting nature by seeking to establish some outside means to encourage direct contact with nature. It is, beyond dispute, the most honored of such institutions which has ever been founded. But it is to be remembered that the Royal Society was not called into being by direct royal decree of a sovereign power, as the Accademia dei Lincei and other later institutions, but by a spontaneous group of advanced independent scholars. Its foundation was laid during the time of Charles II, who was then in the midst of a civil war. Owing to the unusual conditions, men of little political thought, but of much scientific learning, found mutual association of exceeding great comfort and value. About the year 1645 several of these learned scholars, who resided in and about London, and who were interested in mathematics and physical sciences, agreed to meet once a week to discuss various problems and to exhibit such specimens of nature as they had acquired. These meetings were often held in the homes of the scholars, but for the most part at Gresham College, London. During 1648–1649 the meetings were held at Oxford. The interest in the experimental sciences grew rapidly as a reaction against the scholasticism of Oxford and Cambridge, and consequently the membership also grew. In London, in 1659, the meetings were held twice a week at Gresham College, where Mr. Robert Boyle lectured in chemistry, Mr. Christopher Wren on astronomy, Mr. Lawrence Rooke on geometry, and others in related fields. However, the meetings were disrupted for nearly a year, due to the short Civil War, and it was not until November, 1660, that the members were called together again at Gresham College. At this time the "Invincible College," as the group was then known, agreed to form and constitute themselves into a society. At first the membership was limited to fifty-five, but later it extended to properly qualified persons, with a president, secretary and a registrar elected out of their body. The following names stand out in the history of science as the early incorporators and original members: Sir Robert Moray, Henry Oldenburg, Robert Boyle, John Wilkins, Isaac Barrows, Seth Ward, Robert Hooke, Thomas Spratt, John Wallace, Christopher Wren and John Winthrop, Jr., besides some ninety others less well known. In 1662 (July 15th) a royal charter was obtained incorporating under the name of the Royal Society of London. The first meeting of the Royal Society was called at Gresham College by Lord Viscount Brouncker as president, with Dr. Wilkins and Mr. Oldenburg as the first secretaries. The early work and publications of the Royal Society are well known in the annals of the history of science. The *Transactions* and the *Proceedings* are recognized as standard authoritative scientific publications, and the membership to-day is an honored one, its awards being of the highest.

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[1] Due appreciation is here given to the American Council of Learned Societies for grants for aid in securing much of this material.

Previous to the founding of the Royal Society there was established in 1636, in the wilderness of the new colonies of Great Britain, in Massachusetts Bay Colony, a seminary of learning, known as New Cambridge, intended primarily for religious advancement. Many of its tutors were from Oxford and Cambridge Universities, and for the first fifty years its progress was of a slow but meritorious character—more was not to be expected under the trying conditions of the colonies' pioneer life. The early organizers were sagacious men, and accepted the trust laid upon them in its highest regard. New Cambridge later became known as Harvard College, and in its intellectual attainment could not rise higher than its source, as Oxford and Cambridge were yet in the throes of Aristotelian metaphysics and logic.

With Aristotelian philosophy constituting the principal phases of scholastic learning at Harvard College, we have also to bear in mind that other forces influenced the Puritanic philosophy, particularly Calvinism. Together with Aristotelian metaphysics, intellectual progress was apparently confined within a circle. The substance of Calvinistic metaphysics is a form of natural theology, containing all the elements of lost hope for further spiritualistic and intellectual development. A full treatment of Aristotle's metaphysics and Calvinistic theology will be reserved for later consideration; suffice to say that a gradual change finally became possible. This change came in part with the introduction of Descartes' "Logic" by William Brattle, tutor of the college. Most significant, we note the liberal tendency in instruction at Harvard following this date (1724) by one who, contrary to general historical interpretation, was quite liberal and progressive, namely, Cotton Mather, who said, "It is a subject of gratification to me, that you who have been initiated in liberal studies, have adopted a liberal mode of philosophizing, instead of floating about from school to school as if you were literally peripatetica. I doubt not that the Essays of Gassandi[2] are familiar to you; in which he demonstrated that many of Aristotle's positions are deficient—others carried to extreme, others still fallacious. . . ." Again, Mather lays down the principle that the master of arts candidate should be examined more fully concerning astronomy, geometry and natural philosophy. In astronomy, the systems of Ptolemy, Brahe and Copernicus were taught, but the doctrine of Copernicus regarding the universe was finally accepted.

It was not, however, until the new spirit of the academies of science then existing influenced the entire mental attitude of the thoughtful scholars with the new experimental philosophy that progress was made. The Royal Society paved the way in this new humanism for Oxford and Cambridge, and, in turn, for the new school in the colonies.

How far this new spirit of the Royal Society's influence was exerted can be seen by first noting the list of those who in the colony have been honored by the society, and who in turn contributed to the progress of learning and the society's welfare. Massachusetts Bay Colony was represented by nine fellows of the Royal Society: Connecticut by one; Pennsylvania by three; Virginia by three; Rhode Island by one; and the Carolinas by one. In describing their contributions to science and to the Royal Society, each fellow will be considered in the order of the date of his election. The contributions of each of these famous scholars are of a pioneer character, and thus from our present point of view rather crude and childish—yet, how else can a beginning be made? Even thus their own work was accepted as of material value by their great contemporaries, namely, Linnaeus, Woodward, Newton and Halley, Collinson, Flamstead and others.

John Winthrop, Jr., oldest son of the first governor of Massachusetts, had the great honor of being the first colonist elected fellow, in 1663, while he was residing in London temporarily. He was recognized as a man of great learning and therefore assumed responsibility in the local government of which his father was the head. Winthrop settled first in Ipswich and later in the Connecticut colony. In 1634 he was elected governor and continued in this capacity with one or two short exceptions, for the rest of his life. He was educated for the law, but, no doubt, mastered as much of the sciences as was then known, and through his travels and contact with scholars on the continent, he was well prepared to assume leadership in his new home. When he arrived in the colony, his most valuable possessions consisted largely of books, and each year this collection was supplemented by new accessions. From a personal study of the contents of this remarkable collection, as well as from an admirable account recently published[3] it is clear how Winthrop, Jr., became so well versed in the subjects in which he displayed his talent and made his advancement. He is generally credited with being the first chemist and metallurgist in the American colonies, and this, we note, was supplemented with a knowledge of alchemy. Again, he is credited with being one of our earliest medical scholars—a follower of the schools of both Galen and Paracelsus. It is but natural that his interest in chemistry and medicine should have correlated so well, for the practice of each depended upon a knowledge of the other. His discoveries of chemical substance in plants and metals revealed a thorough understanding of the sciences as they were then known. Again, his practical knowledge of chemistry gave him many opportunities to develop mining and engineering industries for the economic progress of the colony and of the mother country, and evidence of his skill is still to be seen in parts of Connecticut. These various engineering developments led to his promoting the pursuit of iron melting and foundry business about 1642. He also promoted many chemical industries, for we note that in 1648 Winthrop was granted a commission by the court of Massachusetts to manufacture salt and saltpeter. Later, in 1651, in Connecticut, he was granted a monopoly for working lead, copper, tin, antimony, vitriol, alum, and other like industries.

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[2] "Institutio astronomica, juxta hypotheseis tam veterum, quam copernici et tychonis," Parisiis, 1645. This little book was virtually the first scientific treatise used at Harvard College.

[3] C. A. Browne, "Scientific Notes from the Books and Letters of John Winthrop, Jr.," *Isis*, 11: 325–342, 1928.

It is therefore not surprising that a man so well known in the art of chemical preparation should have been called upon to extend his usefulness. Records are preserved through letters, wherein extraordinary treatments of the principal chemical remedies which he used for his medical practice are mentioned. The use of saltpeter, tartar, copper, white vitriol, sulphur, iron, rosin, balsam, sassafras were prescribed with other simple Galenist methods. The medical learning of Europe at that time had its source from two schools of practice, namely; the followers of Galen were versed in the use of herbs and plants, etc., and were known as botanical doctors or Galenists; those who were studying the use of mineral properties for patients were called chemical doctors, or followers of Paracelsus. Winthrop's natural liking for medicine seems to have been of long standing. Whether he studied this at Dublin or secured some knowledge of it from his ancestors is not known. However, his first patient was his father, and his service thereafter was called for by Puritans, Quakers, Indians and the Freemen of Rhode Island. Poor and rich alike were treated without fee or reward. He prescribed by letter and personal visits and in each case he sent his affection and godly blessings, showing him to be a man of great human understanding. His preparations and advice for fevers, colds, wounds, poisonous bites, stomach troubles and many other well-known ailments of the colonists form the earliest chapters of the history of medicine in the United States.

When we consider Winthrop as one of the first physicians and chemists, it must be remembered that his official duties as chief executive of the Connecticut colony at Hartford and New London were also demanding time of first importance. The records preserved in his letters and notebooks, as well as a large collection of treatises on chemistry and alchemy, indicated that Winthrop, Jr., was well educated for the pursuit of these interests. Many of his books were from the famous scholars of his period, and his chemical library alone at that time consisted of fifty-two volumes. His papers, letters and library, still extant, form the earliest scientific record and library in the history of science in the United States. These are to be found in the Massachusetts Historical Society library and the New York Society library.

In 1661 Winthrop, Jr., visited England for the third time, and on this occasion it was for the express purpose of securing a royal charter for Connecticut colonial government. This he secured from Charles II as a result of his great influence at home and abroad, which is attested to by his wide correspondence. This mission afforded the rare opportunity at an eventful period in the history of the Royal Society of furthering Winthrop's scientific inclinations, and renewing old scientific acquaintances, as well as making new friends of learning. The society having reestablished itself after a short period of retirement due to a civil war in November, 1660, Winthrop's visit, therefore, was a great satisfaction to the company of scholars anxious to hear of new things from the new world. He was proposed for membership in December, 1661, at a meeting held at Gresham College. The charter for the society was secured in July, 1662, and therefore Winthrop's visit came in the period of reorganization, and he was elected as one of the original fellows on May 20, 1663. On his return to the colony he became the western correspondent for the society, having on his list of correspondents some of the most famous names of the seventeenth century, namely, J. Hevelius, J. Kepler, Sir Robert Moray, Sir Isaac Newton, Sir Christopher Wren, Robert Hooke, Sir Robert Boyle, John Dee, I. Barrows, and many other lesser known scholars. The society having now become firmly established, Winthrop continued to send specimens of such nature as would be of interest to the scholars for topics of discussion, and which later enriched the museum, namely, minerals, plants and "diverse curiosities of nature."

Probably Winthrop's most famous contribution to science and the most unique observation of a natural phenomenon to be found in the annals of astronomy is his supposed discovery of the "fifth satellite of Jupiter." This most interesting record which he sent to the secretary of the Royal Society not alone attests to the colonial scholar's great ability, but his profound understanding of the problems of astronomy as well. We find in a letter[4] addressed to Sir Robert Morey the following account of the fifth satellite of Jupiter. The historical interest surrounding this famous satellite makes it worthy of giving the original account as was written by Winthrop to Morey:

> Hartford, Jan: 27: 1664/65
>
> Honorable S.^{r}—In my former I gave your hon.^{r} an account of the favor I had of your letter by the Hon.^{ble} Colonell Richard Nicolls. I then omitted to acquaint your honor what now I will be bold to add; that havinge looked upon Jupiter w.th a Telescope, upon the 6.th of August, I saw 5 (?) Satellites very distinctly about that Planet: I observed it w.th the best curiosity I could, taking very distinct notice of y.^{e} nūber of them, by severall aspects w.th some convenient tyme of intermission; & though I was not w.thout some consideration whether that fifth might not be some fixt star w.th w.^{ch} Jupiter might at that tyme be in neare coniunction, yet that consideration made me the more carefully to take notice whether I could discerne any such difference of one of them frō the other foure, y.^{t} might by the more twinckling light of it or any other appearance give ground to believe y.^{t} it might be a fixed starr, but I could discerne nothing of that nature: & I consider that the tube w.th w.^{ch} I looked upon them though so good as to shew very clearely the Satellytes, yet was but of 3 foote & halfe w.th a concave ey-glasse; & I question whether by a farre better tube a fixt star can be discerned so near the body of that planet when in the ever bright activity of its light, for, if so, why are there not often if not alwayes seene w.th the best tubes the like or more. Is not Jupiter often in neere coniunction w.th them, expecially *in via lactea?* I have been much in doubt whether I should mention this, w.^{ch} would possibly be taken frō a single affirmation but a mistaken novelty: but I thought I would rather beare such sensure than omitt the notice of it to such worthy friends as might frō the hint of it take occasion to cause more frequent observations to be made upon that planet, & at least this will at length be cleared, whether the light of Jupiter doth not take away the appearance of fixed starrs so neere in coniunction w.th it, as that they should appear w.thin the periphery of that single *intuitus* by a tube w.^{ch} taketh in the body of Jupter & that at the same unmoved aspect: & I am bold the rather to mention this

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[4] Massachusetts Historical Society, *Proc.*, 16: 220–221, 1878.

> as an inquiry whether any such nūber of Satellites or moons hath beene seene by your hon.^{r} or Mr. Rooke or any mathematicians or other gentlement y.^{t} have good tubes & often have the curiosity to view y.^{t} planet, for possibly it may be new to me w.^{ch} hath beene more usually knowne by others, though the notion of such a thinge is not new to my selfe, for I remember I mett w.th the like narration many years since in a little booke intituled Philosophia Naturalis Joh. Phociliden, though then I thought that twas but a mistake of some fixed starrs.

Of course, at first it is impossible to attach any great importance to this observation. We assume, as Winthrop rightly does, that this apparent fifth satellite must have been a faint star in close juxtaposition to other satellites in the field of view of the telescope he had. This was a 3½ foot focal length refractor, with a concave eye glass, which he probably secured along with chemical apparatus during his travels in Europe. However, the following interesting and important historical data are to be deducted from this unique discovery. First, Winthrop is to be credited with being a cautious and keen observer of natural phenomena. He does not ask to have the letter inserted in the *Transactions* of the Royal Society but first requests others possessing more powerful telescopes to verify his observation. This he does by requesting Lawrence Rooke, professor of astronomy at Gresham College and a well-known observer of Jupiter and its satellites, to verify his observations and apparently with no results, as nothing remains extant concerning this fact. Also, in October, 1670, he writes from Boston to Dr. Benjamin Worsley for information concerning this satellite. Again in 1671 after presenting his telescope to Harvard College, he requests his son, then a student, to learn if this satellite had been observed. Second, the fact remains that this object was suspected fifty years after the great discovery made by Galileo, and systematic observations were made in the American colonies. Third, Harvard College possessed the first known telescope in the colonies, which was probably lost in the burning of Harvard Hall in 1764.

Some few years before the late Dr. E. E. Barnard (the discoverer of the fifth satellite) died this account was shown to him, and in reply his remarks are as follows:

> Thank you for sending me the magazine and newspaper cuttings about Winthrop and the fifth satellite of Jupiter. I saw this article a good many years ago. It seems to me it hits pretty hard at Wm. Herschel and Lord Rosse and others with powerful telescopes that are nearer to Winthrop's time! I suppose they never looked at Jupiter. It makes me feel specially humiliated just now, for I have only caught the feeblest glimpses of the fifth satellite with the 40-inch during the past two years. Winthrop's telescope must have been specially good for him to have seen this faint object with his imperfect instrument in 1664. I am comforted, however, by the fact that Dean Swift in "Gulliver's Travels" made the Lilliputians discover the two little moons of Mars such a long time before Hall found them with the 26-inch at Washington. The satellite of Venus was also a product of the early telescopes.

Winthrop's interests extended further than his interest in Jupiter, for in a letter, dated March 18, 1671/72, received from Oldenburg, former secretary of the Royal Society, we note that Winthrop was asked if he had observed a new comet seen by Hevelius on March 6 in the constellation of Orion. Also a new star found in *sub capita* Cygni which was first observed last year (1670) and is again visible.

The large correspondence of Winthrop was the great means of receiving fresh scientific news of events from Europe, supplemented, of course, by the *Transactions* of the Royal Society. There are in many cases no replies extant, showing what response he made to the various suggestions, as more often than not these documents and various specimens of nature, etc., were lost by the frequent shipwrecks of those days.

John Winthrop, Jr., F.R.S., administrator, industrialist, chemist, physician and general student of nature, died in Boston, April 5, 1676, and lies buried in King's Chapel in the same tomb with his illustrious father.

Roger Williams, a friend and an associate of John Winthrop, Jr., and a pioneer religious leader in the colonies as well, was also one of the original members of the Royal Society, having been elected in 1663. There is no record that he complied with the paramount regulation of the society which required the members to sign the roll personally in London, but his name appears on the honored list.

Williams was born in London in 1604, and attended Pembroke College, Cambridge, and was graduated in 1626, and took orders in 1629. The following year he embarked for the colonies, landing at Nantasket. On his arrival in the new land he became minister and teacher, but due to his vigorous and independent views concerning church and state his presence soon became obnoxious to the general community and to the theocratic authorities in particular. His courageous views forced him to establish a separate state of existence, and thus became the founder of Rhode Island. All Williams' life was concerned with education, politics and religion. A careful study of Williams' life reveals no contribution of a scientific nature which would account for his election to the Royal Society unless it was on the ground that he published a philological study entitled "A Key into the Language of America, or an help to the Language of the Natives in that part of America called New England" (London, 1643). It is well to note, however, that twenty years elapsed between the publication of this work and his election to the society in 1663. The majority of his writings were upon "soul liberties and wide religious toleration." Williams' prime contention was that the civil powers should have no authority whatever over the conscience of men. How far reaching this doctrine became is clearly seen in the history and development of the church in this country, and in the political form of our civil government.

Williams' ideas made but little impression on the orthodox puritanism of the time for the reason that New England was too narrow in its views, but it remained for the organized body of the liberals, such as the founders of the Royal Society, to take cognizance of the young rationalist in the colony.

The doctrine of the theocratic form of government, held by the Calvinists and embodying the divine right of kings, was overthrown by an absolute decree which finally made possible and established an uncontrolled sovereignty in the will of man. Colonists in the middle of the eighteenth century began to feel the force of Williams' philosophy of liberal and rational thinking. John Milton spoke of Williams as an extraordinary man and a noble confessor of religious liberty, who sought and founded a safe refuge for the sacred ark of conscience. Williams became first governor of Rhode Island, which office he held for three years, 1654–1657.

He was probably the best linguist the colonies possessed (John Eliot was the first, but not a fellow of the R.S.) which probably accounts for his frequent contact with Milton when he made a visit to London in 1643. Williams' life came to an end near the place which he had first founded in Providence, in April, 1683.

In considering our third colonial scholar from the point of order of election to the Royal Society, there seems to be some doubt or confusion of persons to this claim, between two brothers. Of Thomas and William Brattle, their respective claims to fame rest upon evidence favoring the former. Thomas Brattle was born in Boston in 1658 and graduated from Harvard College as master of science in 1676. He became a successful merchant and later treasurer of Harvard College, which post he continued for twenty years. Due to his wealth and natural inclination he chose to devote much of his time to scientific pursuit, especially in the studies of mathematics and astronomy, excelling in the former. As evidence of his proficiency in mathematics and astronomy, he prepared "An Almanack of Coelestial Motions of the Sun and Planets with their Principal Aspects for the year 1678," published in Cambridge in 1678. Many of these almanacs at that time were prepared and accepted by the college authority for advanced work, on which the master of science degree was given. In this case it is very evident that Brattle prepared his dissertation by computing the elements necessary for solar and planetary data. These little booklets, which are now extremely rare, show a surprising amount of worth-while astronomical information (and at times some astrological) possessed by the colonists' intellectual class. These almanacs contained also much practical information, such as giving the time of the rising and setting of the sun and moon, guiding the scholar and mariner, and locating the planets and stars in conjunction and opposition, giving longitude and latitude. Eclipses of the sun and moon were predicted successfully, and meteorological and historical data were to be found in abundance. In many cases, on the final or concluding pages of these almanacs, the author essayed to give some phases of the history of astronomy or why the Copernicus system should be adopted, or how eclipses occur, etc.

Brattle has the greatest distinction of being the first observer in the American colonies who was of eminent practical service to the great Sir Isaac Newton. It is recorded that his observations on the comet of 1680 (later known as Halley's comet) were furnished to the Royal Observatory at Greenwich. The five or six observations of position on this comet furnished to Halley, then director, and Newton, were of such importance as to time and position that they were used by him in making the first cometary computation thus far made, according to Newton's theory. Crude as these observations for position and time were, they were accepted, however, and through the skilful hands of Halley and Newton were used to excellent results. True, these observations were not made according to the standard astronomical requirements, namely, true time and observed longitude to within a second of time. For instance, using Newton's words, he said: "I was informed by Dr. Halley that on the same day (November 18, 1680) at Boston in New England, in the latitude of 42½° at 5 hr. in the morning (that is 9 hr. 44 min. in the morning in London) a comet was seen near ♎ 14° with latitude 1° 30′ south.[5] In all about six sets of such observations were furnished to the Royal Observatory. He next observed a solar eclipse on June 12, 1694, his account being published completely in the *Transactions* of the society,[6] which in part reads as follows:

> On the 12th of June, 1694, in the morning I went to the Colledge at Cambridge, about 4 miles from Boston, and observed, with the Brass Quadrant there, with Tellescopick Sights, the Rays of the Sun being transmitted through one of the said Sights, on a clean Paper, pasted on a plain Piece of Board, and fastened at right angles at about a foot distance from the said Sight, on which Paper I had drawn a Circle between 2 and 3 Inches Diameter equal to the Suns disk, and within that several Concentrick Circles dividing the Diameter into 24

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[5] Newton's "Principia." American edition by Chittenden. New York, 1848, pp. 481–84.

[6] *Phil. Trans.*, R. S., 24: 1630–38, 1704.

> equal parts, whereby I could observe to 1/2 a digit, the room in which the observation was made was darkened with Blankets, and in order to render the Observation the more Exact (Mr. Henry Newman assisting me all the while) I took the Altitude of the Sun with the aforesaid Quadrant, as followeth.
>
> Observations made of the Suns Altitude before the Eclipse began, in order to rectifie the Watch.

This was not a total eclipse of the sun, for he states that the beginning and end of the eclipse were only 10½ digits where covered by the moon. He observed this phenomenon with care and much preparation, for the problem was of great importance, namely, the determining of the exact longitude of Boston. A comparison of observations with those made in London placed Boston in longitude $4^h\ 43^m$ or 70° 45′ west of London, and the latitude assumed in the calculation was 42° 25′. The unsettled problem of determining the exact longitude was then uppermost before the Greenwich observers to master, mainly due to England's growing maritime power. Further details concerning this eclipse are not necessary here. Another eclipse of the sun was observed by Brattle on November 27, 1703:

> when at half an hour past 8 in the morning, I set my Clock exactly by my Ring-Dial, and at half an hour past 9 they nicely agreed, etc.

And he adds:

> I observ'd this Eclipse with a Telescope of one joynt, 4 foot and a half in length, and had only 2 glasses, so that it inverted the object: and I had a red Glass which suited it, so that I could screw it in just before the Eye-Glass, and was not fain to hold it in my hand, as when I observ'd the Sun's altitude with the brass Quadrant, which was a great convenience.

The next astronomical work of Brattle was the observance of three lunar eclipses, the first observed on February 11, 1700, the second on December 12, 1703, and the third on April 5, 1707. The facts concerning these eclipses are so simple that no mention will be made as to time and position relative to them. Science is also indebted to him for the earliest precise observation known to have been made on the variation of the magnetic needle, which he found to be, in 1708, about 9° west of north. This observation proves that the needle, which in 1782 varied less than 7° from true north, but which since that time has been moving westward until it is now more than 9° west of north, has returned to the position which it held about 200 years before, and therefore that the change is periodical.

About 1689 Brattle visited London and between that year and 1692 he was presumably elected fellow of the Royal Society of London. There is no evidence of his election in the records of the Royal Society except that of his younger brother William in 1713. The question is whether or not there may have been a misprint or omission during the days of uncertain printers or proofreaders, or, possibly secretaries. Our best proof is to be found in a manuscript letter[7] giving a full account of the delusion of witchcraft in Salem, dated October 8, 1692, signed as Thomas Brattle, F.R.S. However, history may state that he is reputed to have been elected. Brattle proved himself a worthy candidate for this honor and must have been recognized by his friend, then secretary of the Royal Society, J. Hodgson, whereas his brother William had no claim or contribution to offer in return for the honor which posterity has ascribed to him. William Brattle was a tutor at Harvard College and published a celestial almanac for 1682. Brattle was practically the first tutor in philosophy in the American colonies, and is credited with having published the first book on logic in the colonies. This book on logic was merely a reissue in part of Descartes'

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[7] Mass. Hist. Soc., *Collection*, 5: 61–79, 1816.

"Compendium Logicae." Descartes' philosophy had become so deeply rooted in Harvard that in 1690 a thesis was maintained in the affirmative by a candidate for the degree of Master of Arts, with the title, "Is doubt the beginning of all indubitable philosophy?," which signifies a characteristic Cartesian philosophical attitude. Brattle's work was used for more than half a century. This was in sharp contrast with Aristotelian and scholastic philosophy taught for the first half century. The new philosophy of Descartes was later reinforced by the great English scholar Locke on "Human Understanding." Thus it will be seen that William Brattle was the founder of the modern philosophical school, established in Harvard in 1690. This may have been sufficient claim for recognition of the Royal Society to accord the honor of fellow to William Brattle. At this late date it is not our purpose to lay open the question of prior right, but evidences are sufficient to show that the Royal Society of London recognized our scholars for their efforts and gave them encouragement and sustained their records in some form of incomplete honors. This was also very evident when we find that our next fellow, John Leverett, from the colonies was elected at the same time as his classmate, William Brattle, for his accomplishments as the eighth president of Harvard College, from 1704–1724.

Thomas died in 1713, and William in 1717, and both lie buried in King's Chapel, Boston.

Between the period in which the two Brattles are reputed to have been elected fellows to the society, came a man of considerable note and ability, both in scholarship and administrative influence. William Byrd II was born on March 28, 1674, in the colony of Virginia, and was educated in England. His election as a fellow of the Royal Society occurred in 1696 at the very early age of twenty-two years, which action took place after he had been called home on account of the death of his father. At this time he brought back with him the beginning of one of the finest private libraries known in the colony. This library was composed of approximately 4,000 volumes of the best literature of the period, and until recent times was kept intact. Although his career was not of a scientific nature, his great influence and encouragement gave the needed impetus to others who were engaged in pioneer scientific work. He was in constant correspondence with Sir Hans Sloane,[8] secretary of the Royal Society from 1693 to 1712, and president from 1727 to 1741 (elected president following the death of Sir Isaac Newton). These letters have much to say concerning the native plants and minerals of Virginia, and emphasize their experimental, as well as their economic uses and their medical properties. His relations with the Royal Society were most cordial, and he constantly endeavored to promote the influence of the society in the colony. In a communication he urged strongly that the society send over properly prepared botanists or natural philosophers to explore the wonderful plant and animal life of Virginia instead of accepting the reports of discarded ship's doctors who knew little of the curative properties of plants, and who were incapable of making great discoveries.

As Byrd had little or no scientific training, he made no attempt in the experimental studies, but forwarded his plants, their roots and seeds, to Sir Hans Sloane, who in turn described and classified their parts and medical properties. In his letters he described his meetings with Dr. John Tennant and Mark Catesby and other wandering botanists in search of plants and minerals, from whom he secured new information of scientific value.

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[8] Sir Hans Sloane was a distinguished botanist of England, and his great collection of books, manuscripts and specimens laid the foundation of the British Museum in 1753.

Byrd published only one paper in the *Transactions* of the society, and in this he gives his observations of coloration upon a Negro body. His paper was entitled "An Account of a Negro-Boy that is dappel'd in several Places of his Body with White Spots."[9] His later writings, published in 1841, and known as "The Westover Manuscripts," were not brought out until three years before his death. "The Westover Manuscripts" were composed of: (a) "The History of the Dividing Line Between Virginia and North Carolina," (b) "A Journey to the Land of Eden," (c) "Progress to the Mines." The first paper is a report of a commission, of which Byrd was a member, which was appointed in 1728 by His Majesty to prepare and survey a boundary line between Virginia and North Carolina running through the Dismal Swamp. This was apparently the first attempt to accurately determine a boundary line between the colonies or states. Later a revised survey was made, and Byrd called his report "The Secret History of the Line." In the second and third papers he gives an account of the opening of iron mines and the inspection and progress of mines in operation. These papers do not possess great scientific value, much less a description of the land he visited, but merely describe in detail the state of civilization on the frontier. They are interesting, however, from a literary point of view.

One of Byrd's most important activities during his life was the endeavor to further colonization in the colonies, and this is brought out in his correspondence with John Bartram, botanist, of Philadelphia, and other influential men in the colonies, for he foresaw the great economic and social importance of the colonies to England. Byrd contributed also largely to the economic progress of the colonies by his large land holdings, the importation of slaves, sugar, ginger and other commodities for the comfort of colonial life. He also greatly advanced the intellectual life of the colony by encouraging the study of all phases of natural phenomena, the importation of scientific instruments, books, pictures and music, and was recognized as a man of great power and authority. Byrd died at Westover on the James River (one of the most famous of Virginia plantations) on December 4, 1744, and lies buried on his estate which he loved so well.

John Leverett was born in Boston, Massachusetts, on August 25, 1662, and was educated at Harvard College, from which he graduated in 1680. He also became tutor of the college, but due to his active interest in law he later practiced in the courts of Massachusetts with much success before he was elected president of Harvard College. Leverett was a liberal, forceful in his views on religion and education, and was a man of exceptional ability and scholarship, and therefore showed excellent and wise leadership during his period of administration at Harvard. What reason the Royal Society had for conferring in 1713 a fellowship on Leverett is not known, except possibly for his high standard both as a leader at the bar and in scholarship and administrative power. This seems somewhat unusual at that time, since Leverett had made no particular contribution to science in the colonies. The fact remains that he was recognized as a distinguished citizen and an honor to Harvard College.

Cotton Mather, the celebrated minister and writer of Massachusetts, according to printed records became our sixth scholar in the young colony to be recognized by the Royal Society. His election as fellow took place in 1713, the same year that Thomas and William

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[9] *Phil. Trans.*, R. S., 19: 781, 1697.

Brattle and Leverett were reputed to have been elected. Mather was born in Boston, February 12, 1663, and graduated from Harvard College in 1678, when scarcely fifteen years of age. He became mostly interested in theology, but probably is best remembered in literary history as the first historian of Harvard College. This early history is the most complete account of the founding and the first years of the college. This account appeared in his "Magnalia" which was published in London in 1702. Mather was considered the most learned man of his period, and while educated not as a scientist, to be sure (no set discipline was then known for a career as a student of nature), he, however, was a diligent and acute observer of natural phenomena, as we shall show. Simple as these observations were, and crude as their deductions were, with no apparatus or instruments in the aid of the study of these various phenomena of nature, they were precisely the sort of thing and methods that the naturalists were noting and publishing at that time in England, as well as on the continent, and fortunately most of them were really worth noting. The education of the student at the young college in Cambridge did not, in Mather's period, include the first principle as to how to observe nature. Natural philosophy consisted of a little of astronomy, physics and geography and some lessons in geometry. There were no observatories or laboratories, and the student learned directly of nature through books. Botany, zoology, geology and chemistry were hardly even known by their terms as designated. Little need we wonder that science made slow progress, and yet, considering the period historically, the intellectual interest in natural phenomena was manifestly acute. Mather was not a tutor at Harvard, and was not quite at agreement with the form of instructions then given there, for as he said, avoid philosophical romances and get as thorough an insight as you can into the principle of our perpetual dictator, Sir Isaac Newton.

In November of 1712, Cotton Mather prepared a series of thirteen letters of natural and geological history from New England, and addressed these to the secretaries of the Royal Society, namely, John Woodward, an eminent paleontologist, and Richard Waller. There is recorded in the various manuscript books of the Royal Society the fact that Mather had sent a series of 37 communications to the society, but at present we can not take cognizance of them all. Many of them, however, were published in abstract form in the *Transactions* of the society.[10] Mather collected and sent to the museum in 1714 specimens of bones, presumably of antediluvian creatures, fossil teeth and such other subterraneous curiosities as were possible to discover in the unexplored regions of New England. His correspondence with the distinguished secretary, Dr. Woodward, was most timely, as the learned secretary was extremely anxious to procure all natural phenomena that the new colonies could afford. Again, in September 24, 1716, he sent to James Petiver, F.R.S., a distinguished botanist and entomologist, a few dried colonial plants, with observations upon them. This list and comments were published by Petiver with due credit to Mather in his "Nature Collectanea" in 1717. His diligent interest and communications continued to expand to such a large variety of objects that a detailed account of each is not possible in this paper. Mather was also active in observing fauna of New England. His notes on the moose, rattlesnakes, pigeon, worm and fishes, and other specimens of animal life were included in his realm of observation and also such as monstrous births of human beings as well as the lower animals. Mather is probably one of the earliest practitioners in the medical understanding of the treatment of yellow fever. In public print and by private correspondence he gives an account of the method and success of inoculating for smallpox. One of his latest biographers[11] speaks of him as the pioneer founder of the school of inoculation during the frequent smallpox calamities in New England. For this he was persecuted, as many prophets of past ages have been and still are. Mather had secured his information from the Royal Society *Transactions*,[12] and his early training as a physician gave him confidence in its treatment, but the proposal of the method to prevent smallpox infection was startling to many of the learned of the period. Those to whom he gave the treatment responded, and he very hopefully predicted that the results would be the means of preserving many lives. Again, in the realm of physical science, our scholar has left record in the form of letters and notes upon the action of snow, wind, rain, thunder, lightning and the Aurora Borealis. Also a curious account of the action of the moon upon wood is extant. To understand and appreciate more clearly the method and spirit of this Puritan scholar, it is well to read his letter concerning his observations on the details of a remarkable winter in 1717. It is probably one of our best examples of quaintness and his keenness to record all natural phenomena still extant of the seventeenth century writings.

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[10] *Phil. Trans.*, R. S., 29: 62–71, 1714.

Cotton Mather died in 1728 and lies with his ancestors in Copp Hill burying grounds, Boston.

Paul Dudley, our next ingenious scholar and fellow of the Royal Society, was born in Roxbury, N. E., in 1675 and graduated from Harvard College in 1690, educated for the law. Dudley came from the distinguished family of early founders and governors of the Massachusetts Bay Colony, and himself later became chief justice of Massachusetts. His innate interest in the laws of nature, however, led to his writing on the natural history of New England, including the weather and earthquakes. The appreciation of Dudley's observations and writings, which in all were about 25 papers, led to his being elected a fellow of the Royal Society in 1721. However, all his communications were not published in the *Transactions*, as some of these were merely notes or records of observations for the immediate use of members of the society, who were at all times intensely interested in whatever new came from the virgin land of natural phenomena in the colonies. Simple as these discoveries were, they were, however, entirely new to the fellows whose imaginations were constantly stirred, and consequently their encouragement gave the colonial scholars the needed impetus. In return the colonists received books, especially the *Transactions* of the society. Dudley's first paper[13] sent to the society was an account of the method of making sugar from the juice of the maple tree. The method of drawing off maple sap at that time does not seem to differ a great deal from that of to-day. An interesting feature of Dudley's paper is his final comment on maple sugar, wherein he pointed out that its medical virtues exceeds that of the West Indies sugar. This fact was highly important for the colonists, as in all their studies there was an economic and medical value to be sought. Winthrop, Jr., and Cotton Mather were constantly seeking to adapt the juice, bark and leaves of fruit trees for medical purposes. Dudley's keenness for useful recipes of household importance is manifested by his account of a new sort of molasses made of apples;[14] he details the method of preparing and caring for it. This is also a New England invention. Dudley again revealed himself in the order of being the first horticulturist in America.[15] His next communication to the Royal Society was an account of the fruit trees of the fields and orchards of New England. He describes the trees in their physical nature and their fruits in comparison with those of old England. He informs the members of the society of the amount of cider which may be obtained from a certain number of bushels or barrels of apples, and makes further remarks concerning the qualities of pears, peaches and cherries. Also, he describes various other trees to be found in the forest and the method of transplanting by seed or grass. From his garden the vegetables are detailed in general, such as the onion, pumpkin, Indian corn, beans and hops, showing how to plant and grow these by the various experimentation he carries on. It may seem that he anticipates Luther Burbank in the propagation of better fruits, especially in the culture of corn. Dudley writes an interesting paper upon an ingenious method of locating beehives in the forest.[16] This method consists of setting two or more bees free from two different points, after they have acquired some sugar or wax set down for them. The hunter for wild honey then observes the direction of the bees' flight with the aid of a compass, rule and paper. He moves on about a hundred rods distant from the first point and releases the second bee, and again with the compass notices the direction of its flight. The intersection of these two directions or lines will locate exactly the tree in which these bees have their hives. The mathematical certainty of this method, Dudley says, is one used continually by hunters. The bees were originally brought over by the early colonists and were not known by the Indians, at least, there is no Indian name for them, except "the Englishmen's fly."

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[11] Barrett Wendall, "Cotton Mather, the Puritan Priest," Harvard Press, 1926.

[12] *Phil. Trans.*, R. S., 29: 72–82, 1714.

[13] *Ibid.*, 31: 27–28, 1720.

His next contribution[17] was a paper describing a poisonous wood-tree called "swamp sumach." Dudley, not being a trained botanist, merely gives a local description of this tree or shrub. It was through the botanist of the society, to whom he corresponded regarding his specimens, that he received further comments regarding its scientific nomenclature. Mr. Catesby, in the Carolinas, had sent to the society a quantity of this "Water Shrub," together with the seeds. Dudley writes of the poisonous effects on the body as he observed it on his friends, as well as possible cures. However, he did not in this case actually send a specimen due to the apparent danger of the effect of merely touching or smelling of the wood which would cause inconvenience to the members of the society. The botanist of the society speaks of this plant as a species of *Toxicodendron*.

The rattlesnake was apparently numerous in the colonies, according to Dudley.[18] Again we find his description very complete and accurate and full of scientific interest, especially in the manner of describing their habits and dangerous contacts. It seems that much of this information concerning the moose, deer and snakes as well as plants was obtained through friendly Indians, but in the main through personal investigations which he was quite capable of making, less scientific probably, due to many cases in which he does not give a physiological description. Methods of dissection and taxidermy in order to make a comparative study of genus and species were not attempted; even in Europe this was not then the mode of scientific work.

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[14] *Ibid.*, 32: 231–232, 1722.

[15] *Ibid.*, 33: 194–200, 1724.

[16] *Ibid.*, 31: 148–150, 1721.

[17] *Ibid.*, 31: 145–146, 1721.

[18] *Ibid.*, 32: 292–295, 1723.

The account of the fauna of the new country has been described by other observers, but Dudley seems to have taken very careful notes of the general appearance of the various species, their life and habits, as well as their economic bearing. No anatomical or physiological studies were made, as this did not concern the fellows, with whom at this time zoology as a science was not established; at least, it was not in the colonies. Dudley's knowledge of the moose deer[19] was derived from an all-year study, in which he made observations and comparisons and corrected erroneous information sent by Josselyn.[20]

Dudley's last two communications to the Royal Society were essays of a highly scientific character. He had applied himself with increasing diligence to the study of natural history, which fact is borne out by the high character of his later papers. The first of these two papers is entitled "An Essay upon the Natural History of Whales, with a particular Account of the Ambergris found in the Sperma Ceti Whale."[21] In this paper he describes in detail the physical characteristics, the mode of living and the manner of killing of the several species of whales found along the coast of New England, namely, the whalebone whale, scrag whale, finback whale, bunch or humpback whale, and the sperma ceti whale. He lays more stress on the economic importance of the whales than on their scientific aspect. He enumerates with great care the amount of oil each species produces at various ages and also the amount extracted from the various parts of the bodies. He does, however, mention the medical value of certain parts of the whale, for he states in regard to the sperma ceti whale that

> One of our Country Doctors tells me, that the Tooth of this Fish, shaved or powdered, and so infused in Liquor, equals the Hartshorn, and has been used in the Small Pox, and given to Lying-in-Women, in Case of Sickness, with Success.[22]

The last paper was a letter addressed to the secretary of the society, dated November 13, 1727,[23] which is "An Account of the several Earthquakes which have happen'd in New-England, since the first Settlement of the English in that Country, especially of the last, which happen'd on Octob. 29, 1727." This paper was prepared apparently in obedience to the wishes of the members of the society, for he takes great pains to prepare a historical account of these earthquakes. Since he does not give a very scientific description of the earthquakes, the dates may be of interest. The first quake recorded in New England history seems to have been on June 2, 1638, and in view of the sparsely settled condition of the colony at this time no other earth movements were recorded until 1658, when another earthquake was noted, but Dudley makes no mention of particulars regarding it. He records that on January 31, 1660, another great earthquake occurred, and two years later on January 26, 1662, about six o'clock at night a severe earthquake took place and was followed by two others in a duration of several hours. In 1665, 1668 and 1669 several slight tremors were recorded, but from the last date until 1727 apparently no earthquakes took place.

According to Dudley's reasonings, these quakes were caused by motion of the earth's crust, but the causes of these earth movements were not clear to him, for in the study of the last earthquake he proceeds to note the weather of the seasons preceding the earthquake. Having noted the temperature, the direction of the wind, the amount of rain, frost and snow, as well as the thunder and lightning, he proceeds to give us a theory which for its quaintness is quoted verbatim.

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[19] *Ibid.*, 31: 165–168, 1721.

[20] J. Josselyn, "New England Rarities Discovered," 1672.

[21] *Phil. Trans.*, R. S., 33: 256–269, 1725.

[22] *Ibid.*, 33: 259, 1725.

[23] *Ibid.*, 39: 63–73, 1735.

> By this short Journal of the Weather the Learned will be able to some measure to say, how far our Earth might be dispos'd to, or prepar'd for the Earthquake that followed; first by a long continued Drought and extreme Heat, whereby the Earth became more porous, and abounded with Exhalations or Vapours inflamed, and which afterwards being shut up by the succeeding great Rains and Frost, and thereby hinder'd from an ordinary and easy Passage through the Pores and Common Vents of the Earth, worked so much more forcibly and terribly upon one another. But Philisophers not being yet agreed on the Nature or certain Causes of Earthquakes, I pass on to the second Thing which I proposed to enquire into, Viz. what Kind or Sort of Earthquake ours was. *Gilbertus Jacchaeus* in his *Institutiones Physicae, cap. Terrae Motus* distinguishes Earthquakes into four Species; wherein he agrees with Aristotle and Pliny, with whom the first Species is a Shake or Trembling, and by them liken'd to the shaking Fit of an Ague. I cannot yet hear of any Breach or Opening of the Earth, through the whole Extent of our Earthquake. It has been said by some that were abroad, that the Earth sensibly rose up, and so sank down again; but I much question the Truth of it; for if there had been any such Succussion to raise the Earth to any considerable Height, the Houses would certainly have tumbled down, or the Exhalation forced its Way by some Breach. Nor was our Motion of the Earth that which Aristotle and Pliny call a Pulse or an intermittent Knocking, but one continued Shake or Trembling; and therefore must be ranked under the first Species, viz. a Tremor or Shake, without altering the Position of the Earth, and left all things in the same Posture in which it found them, except the falling down of the Tops of some Chimnies, Stone Walls, etc. without doors; Dishes and some other Things within doors; which I shall observe when I come to speak of the Degree of the Shake.

Crude as his description and theory concerning earthquakes were, the exact truth concerning the causes of earthquakes was not known until some thirty years later, when John Winthrop IV brought out the first scientific explanation of these phenomena.

With several minor communications to the society, Dudley closes his active scientific career, which began in 1720 and ended in 1735, a period constituting a most worthy chapter of pioneer scientific endeavor in the colonies. Dudley's later years were devoted to the practices of the law, and for sixteen years he maintained the tradition of the family in this respect. He died in 1751 and lies buried with his ancestors in the old Eustis Street burying ground in Boston.

In contrast to the placid lives of the preceding scholars, where Calvinism seemed not to have been disturbed by the men collecting specimens and recording observations of natural phenomena, we shall now treat of one who was far above the highest trained minds and theological dogmas of the colony, and who became a storm center, epoch-making in medical history.

Zabdiel Boylston, a self-educated physician, possessed a scientific spirit rare for the age of intolerance to deal with. He apparently did not come under the spell of Puritanism and therefore seemed almost modern in his will to do as his conscience dictated, and this in spite of his close relation to the high priest of Puritanic Calvinism—Cotton Mather. Scientific logic apparently met its antithesis in full force, and to the incredulous it seemed that the doctrine of Calvinism was rudely torn asunder. Boylston was born in Boston in 1679 and received much of his education from Dr. John Cutter, an eminent practitioner of Boston. Young Boylston was not sent to England for his medical training; in fact, the second generation of physicians were trained by the school of hard experience and self-effort. This system prevailed for over a century in New England before the first medical school was established in 1765.

Boylston will be long remembered for being the first to introduce in the colony a system of inoculation against smallpox, at the great risk of his life and reputation. Boston had during the seventeenth and eighteenth centuries six serious epidemics until the general use of inoculation by transplantation was fully accepted. The original method of inoculation was first published[24] as a contribution by the Royal Society in 1714. This was first noticed by Cotton Mather (then recently elected fellow) during one of the epidemics. Mather, out of despair for his own family, urged the doctors to undertake the general use of the method described. However, so radical were such conditions of treatment that the credulous Puritans hesitated strongly to allow its adoption. The alertness and independence of mind of a man like Boylston did not allow the opportunity to pass in order to find some means to check this dreaded disease. In this new innovation, he was fully supported by Mather and some of the leading scholars. After many secret inoculations as well as open treatment, and regardless of the edict against this method, the dreaded disease was finally checked and the colony experienced its first rational understanding of scientific medicine. The history of the opposition to this practice is an interesting chapter in medical progress in the United States, but only a brief summary of it may be given.

This method was used previous to 1713 by the Turks, Circassians and Georgians, especially so in Constantinople, where the knowledge of its practice was transmitted to England by means of a letter from Emanuel Timonius, M.D. Oxon and Patav, to John Woodward, and presented to the Royal Society by him in 1714. The procedure used in those days may be summarized in a few basic steps:

(1) The vaccine was procured from a young healthy individual who had the smallpox for at least 15 days from the first sickness.

(2) Pus was forced from one of the tubercles into a glass receptor, or vessel.

(3) Pus was then kept at body or near body temperature, until ready for use, which was in one or two hours.

(4) The patient to be vaccinated was placed in a warm room, and several scratches sufficiently deep to draw blood were made on the forearm.

(5) The smallpox pus was rubbed over the scratched area of the skin, taking care to force as much of the pus as possible into the scratches.

(6) The area was covered with some protection, such as a half walnut shell, and the patient was restricted to a diet which excluded meat and broth for at least 20 to 30 days.

(7) Best results were obtained when the vaccination was performed in early winter or spring.

While this method was rudimentary and lacked the important aseptic conditions for safe administration, it was quite successful, and few cases failed to recover from the vaccination.

The method used to-day varies from this, not in principle, but in the application of steps more essential for the safeguarding of the patient. The most important of these is the use of asepsis throughout, including the use of a vaccine which is as sterile as is possible to secure, and absolutely containing no pathogenic organisms. Second is the use of a vaccine which has been attenuated by producing cow-pox in a young calf by inoculation of the smallpox virus, and later collection of the pus from the tubercles of the cow-pox and using this as the vaccine, instead of the more potent virus from the smallpox tubercle of the human.

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[24] *Ibid.*, 29: 72–82, 1714.

After his great success in the treatment or prevention of one of the worst plagues known to man, Boylston visited England, presumably at the invitation of Sir Hans Sloane, then the leading physician of England, and president of the Royal Society. Boylston's reputation was generally acclaimed as the largest and most successful inoculator, but during his stay in England he gave no treatments, fearing he would be misunderstood, but no doubt gave demonstrations before the Royal College of Physicians, of which he was made a member in July, 1726. Boylston published very little in the *Philosophical Transactions*, but at the request of the learned physicians of London he prepared while there an historical account of his work. He did, however, publish only one contribution in the *Transactions* of the Royal Society[25] entitled "Ambergris found in Whales," but it was primarily the pioneer work and experimentation of inoculation for which he was honored as fellow of the Royal Society in 1726. Boylston was not only distinguished as a medical man, but had acquired no mean reputation as zoologist and botanist, and was universally respected and loved because of his moral character and benevolent disposition.

Little remains to be recorded of Dr. Boylston's career after he returned from London in October, 1726. He resumed his practice, which must have been greatly enlarged after the reception accorded him in London, and lived long enough to see inoculation well established and successful, and to know that he was recognized as one of the world's greatest benefactors. He died at the age of 87 years, March 1, 1766, and lies buried in the old cemetery of Brookline, not far from his boyhood home.

A contemporary and associate of Cotton Mather was John Winthrop, a grandson of John Winthrop, Jr. Winthrop was born in Boston in 1681, and graduated from Harvard College in 1700. Nothing seems to be known concerning his early life as a student which would give promise as a scholar, which he later became. That he was interested in natural philosophy was no doubt inspired by the work of his grandfather, who was the observer of the supposed fifth satellite of Jupiter.

Winthrop became a fellow of the Royal Society in 1734, in recognition of his service as collector and student of minerals, and other specimens of geological remains, such as fossils, shells and stones with interesting conglomerations. These contributions which he presented to the society's museum were of inestimable value to the paleontologists and geologists as such in those days. The colony of Massachusetts Bay was then the greatest research field which always caused wonder in the scholars at home as to the natural phenomena they found, not alone in the field, forests and streams, but in the heavens. It is no great wonder that the Royal Society was always ready to acknowledge the real service to science thus rendered by honoring those who supplied material from the unexplored regions. Winthrop was a diligent collaborator with Cotton Mather in collecting specimens, but he himself presented over 600 specimens. He showed scholarship in the method of describing, classifying and cataloguing these specimens in their very general relation to surface configuration. There seems to be no record of any chemical analysis, close study of characterization, classification with respect to their occurrence in nature and reference to their mode of formation in rock masses, or alterations which they may have undergone. His observations and remarks, however, upon the medical properties and use of certain minerals, roots and shells were frequently sagacious and just, and therefore great credit should be accorded our first systematic collector of mineral specimens. Imperfect as the science was, Winthrop greatly aided in making progress towards establishing mineralogy as a science. However, the fellows of the Royal Society took occasion to make analysis of the various specimens of minerals and there is recorded that a discovery of certain well-known acids was made. The original manuscript of the catalogue which he prepared with great care is now preserved in the archives of the Royal Society. Selections of this ancient catalogue were printed in the *American Journal of Science.*[26]

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[25] *Ibid.*, 33: 193, 1724.

The last part of Winthrop's life was spent in England, and there he became a prominent member of the society. He died in London, 1747. A most unusual honor was accorded Winthrop by the secretary of the society, Dr. Cromwell Mortimer, also fellow of the Royal College of Physicians, by dedicating the 40th volume of the *Transactions* to him. In part, Mortimer states:

> Sir,
>
> Personal Friendships and Favours are become the trite Topics of Dedications and public Addresses, as if it concerned the Public to have upon Record the mutual Regard, private Persons may have to each other: Therefore without expatiating here, so far as Gratitude might lead me, on the many Favours you have honour'd me with, I shall confine myself to the Relation Your Illustrious Grandfather had, and Yourself have, to the Royal Society. . . . The extraordinary Knowledge, you have in the deep Mysteries of the most secret Hermetic Science, will always make you esteemed and courted by learned and good Men; but I forbear to say any more, lest the Trouble I have given you by this long Address should be a Trespass upon your Patience; in which Case I know your Goodness will forgive me; and I hope you will be persuaded, that I am upon all Occasions, with the greatest Sincerity,
>
> Sir,
>
> Your most affectionate Friend, and
> obliged humble Servant.

(To be concluded)

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[26] *Am. Jour. Science*, 47: 282–290, 1844.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE ROMANCE OF MEASUREMENT

By HENRY D. HUBBARD

ASSISTANT TO THE DIRECTOR, NATIONAL BUREAU OF STANDARDS

WHAT scope there is in measurement, from stars to atoms, measuring the age of the earth, the rate of cooling of our sun, the temperatures of other planets, timing radio echoes from distances beyond the moon—measuring almost everything.

Down the ages from prehistoric times came the art of measuring by which things are dimensioned for utility, by which time and place are measured for every fact and act of life. The measuring stick is a scepter in the hand of science; a tool of discovery, of record and of use of exact knowledge. The gradual rise of the art of measurement gave no sign that in this century it would reach a commanding place in human affairs.

In days of old a poor man in thoughtful mood asked a wise man, "Why am I poor?" The wise one cut a staff thigh high, cut notches in it a hand width apart, gave it to the poor man and said: "I give you the scepter of success, a measuring stick. Measures rule the world. They come in pairs—the measure of the sandal must match the measure of the foot. So all things are made to measure, always two matched measures. Let this stick measure what you make, measure well for use. Three loops of cord make it a balance to weigh what you buy or sell. Set it upright in the sun and the stick will measure the shadow hours of time—allot them thy tasks. Tune thy life to its circling shadows. When in spring the noon shadows grow long is time to plant. Measure your portion and your neighbors'. Make wisely, measure truly, trade justly, and you will prosper."

Thus spake the wise man of the legend. To-day more than ever measures rule, for commerce is the exchange of measured things. Every transaction has five measures—quantity, quality, value, time and place. All are measured —quantity by a number and a unit; quality by measures of its properties; value in terms of weight of gold; place east or west of Greenwich, north or south of the equator, up or down from sea level; and time, in terms of the turning earth, the clock, and of its trip around the sun, the calendar.

Measures are miracle workers, when by matching the measured curvature of glass to the measured defect of the eye we restore sight to the aged and perfect the vision of youth. Success in all things is the matching of a measured means to a measured need, shoe to the foot, glove to the hand, key to the lock. We may measure key and lock to a thousandth of an inch, but some measures need no unit. Without a unit a singer matches by ear the pitch of her voice with that of the piano. Without a unit a violinist varies the length of his strings to play true pitch melodies.

A shoemaker of Old Pekin makes shoes with no unit of measure and no measuring scale. A strip of blank paper and his thumb nail are his measuring tools. He transfers the foot measures to his paper slip, using his thumb nail as a marker. Skilfully he transmutes these measures into perfectly fitting shoes, without a unit of length.

The Chinese have units of measure, but they differ for each trade and each place. A cloth merchant may buy and sell at the same price. He buys by a long measure, sells by a short measure, and thus makes a profit. The Chinese travel unit, the "li," is longer on easy roads, so that a downhill trip to town may measure fewer "li" than the uphill trip home. The Chinese unit of weight for rice is the "catty," but the unit grows smaller from rice field to tidewater as the coolies carry the rice bags to market. The reason is simple; each coolie takes out his pay in rice. The rice bags reach seaboard lighter for the tax, but weighing the same number of "catty" as when they started.

Crude measures pass, and by modern methods scientists measure accurately how things happen in nature and in experiment—at what heat and pressure a crude oil cracks into gasoline, or carbon dioxide becomes "dry ice," or air becomes a liquid flowing like water, and countless other phenomena occur.

Science makes vast numbers of such natural measurements—melting points of solids, weights of atoms, lengths of light waves, properties of materials. In such measures lie latent the means to alter nature almost at will and make it serve our purpose with almost magical power. Such measures build civilization. They are the numbers which rule the world of enterprise, the unseen frame of all achievement.

Measuring tools evolve from simple origins—a stick, a shadow, a gourd, a stone—to-day they number thousands. They give us new senses, enable us to detect invisible light, to feel magnetic forces, to sense a thousand things otherwise imperceptible. With the crescograph one can see the movements of growing plants. A lens-and-mirror device measures the diameter of stars, a feat comparable with measuring a coin fifty miles away.

The radioactivity of radium is measured by the motion of an electrified strip of gold foil, while electrified quartz threads are sent up ten miles to measure cosmic rays. A six-ounce device in a balloon rises sixteen miles to bring back automatic weather records of temperature, pressure, and humidity. We measure air moisture by the stretch of a hair. In the fog-signalling device at the Antioch Light one hundred human hairs are so set that in fog dampness they stretch and thus turn on the signal.

Ingenuity in measuring rarely excels the bit of genius by which we literally hitch our wagon to a star. An automatic device in Paris catches a star's image at meridian, turns its light into an electric pulse, amplified and broadcast as a radio time signal. Time and tide wait for no man. But a marvel among measuring devices takes thirty-seven measured facts set into its mechanism to predict years ahead the height and time of day of all tides for every port of the world. Mathematically minded, this device turns the measures of yesterday into prophecy for to-morrow to guide ships unbuilt on voyages yet undreamed of.

Sound and radio waves are used to measure ocean depths, the thickness of glaciers or the height of the radio ceiling of our air. Radio waves go up with the speed of light and echo back from the magnetic layer of our atmosphere over a hundred miles up. By timing the echo we measure the tides in this magnetic ceiling which may rise fifty miles in a magnetic storm. Echo times indicate that some radio echoes come from distances farther than the moon. Then, too, sound waves are directed to sea bottoms and their timed echoes measure ocean depths to aid navigation. By similar means the thickness of glaciers is measured by timed echoes of sound sent through the glacier to echo from the rock beyond.

Measures are tools of discovery. One interesting story tells how measures solved the mystery of the breeding place of the Atlantic eel. Out from the rivers swarm the eels each autumn, soon lost to sight at sea. Where they bred, no one knew. Catches of eels were measured from millions of square miles. Measuring their way from all directions men followed the lines of shortening eel lengths to the size of the baby eels—all trails leading to the Sargasso Sea, which proved to be the cradle waters of the eels, a mystery solved by measuring lengths.

Nature does not efface her past. She leaves a record, a history writ in measures. Tree rings thousands of years old reveal the growing weather year by year, climatic history of ancient times. How the rise and fall of tree growth varying in eleven-year rhythms were matched by a similar rise and fall of growth in the number of sunspots also in eleven-year rhythms is an interesting story, for phenomena which vary alike reveal cause and effect relations of profound importance to man.

Measures are great teachers, reducing error, diffusing truth. They dispel error by teaching that a pint's not a pound the world around and never was, anywhere in America; that the needle is not true to the pole; that the so-called "solar constant" is far from constant; and that there are no fixed stars. Measures tell truly how much a pint of liquid weighs, how far the needle wanders from true north, how the solar constant or sun's heat and light vary from day to day; and how many miles a second the so-called "fixed stars" are moving.

Measures teach truth vividly, with almost dramatic effect. We all conceive the atoms as being very small, but we learn how small an atom is when measures tell us, by thirty methods, that a billion atoms side by side measure one inch, or, more startlingly, that if all the atoms in a thimbleful became tennis balls the balls would cover the United States hundreds of feet deep.

Again we all have some idea of the Gulf Stream, but how vastly more vivid it becomes when measures tell us that the volume of flow of the Gulf Stream off Miami is fourteen cubic miles an hour, or equal to one thousand Mississippi rivers in one.

Men who measure do not lack devotion. Countless explorers of nature in the laboratory, the observatory, or at the ends of the earth, in the craters of volcanoes, or in the high air or deep sea sacrifice to gather measures of nature and her phenomena. Galileo "the father of laboratory science" was its first victim. In the great Tokyo earthquake of 1923 the Japanese experts stuck to their work of measuring the earth movements while they could see their own homes going down in ruins and up in flames—a devotion which gave the world its most accurate scientific narrative in earthquake annals.

The engineer puts measures to work in skyscraper, bridge, and other structures. Measures flow through his pencil to scale drawings, each point a location, each line a length to be translated into steel or stone. He matches measured strength against measured stress. Thus by means of measures of strength and dimension the engineer builds his dream of stability into the structure and the architect actualizes his dream of beauty. When the cathedral stands finished, strong and beautiful, we forget the measures, but they remain forever the strength and beauty of the cathedral.

POISON IVY AND WHAT TO DO ABOUT IT

By Dr. JAMES FITTON COUCH

WASHINGTON, D. C.

THIS is the season of the year when mankind becomes acutely conscious of the poison ivy plant. With the coming of spring the nature lover begins his excursions into the countryside, rambling over fields and through woods, and there is an immediate increase in the number of victims of this irritant pest. Some will escape with a few blisters or an itching rash; others will suffer a general reaction accompanied by swelling, chiefly of the face and hands, and may become so seriously sick as to be confined to bed for several days. Ivy poisoning usually is not a serious matter and frequently is a subject for jocularity, the sufferer receiving little sympathy from those unaffected. In a small proportion of cases, however, ivy poisoning may be very serious and may even terminate fatally. Four cases of death from this cause have been reported, so ivy poisoning is not a matter to be taken lightly.

The first thing to do about poison ivy is to learn how to recognize the plant. Many persons, some of them susceptible to the poison, do not identify the plant when they see it. There are a lot of contradictory stories about the appearance of the plant and a variety of common names applied to it, all of which tends to confuse the average individual's ideas on the subject. The plant is called poison ivy, poison oak, poison sumac, poison creeper, markweed, mercury, picry and three-leaved ivy. Sometimes the confusion is increased by applying the name, poison ivy, to plants that do not cause a dermatitis or inflammation of the skin, such as the mountain laurel, which is called poison ivy in some sections of the South.

To begin with, poison ivy is not an ivy at all. This name was applied to it by Captain John Smith, who was blistered by it and who fancied that it resembled English ivy. Poison ivy belongs to a genus of plants that the botanists have named *Rhus*. This genus also includes the common harmless sumacs. About twenty species of the genus are known to produce dermatitis, but only three of them are widespread enough to be of importance in this connection. Two of these are sometimes of shrubby growth and sometimes are found climbing, ivylike, upon walls and trees. In the East the species is known as *Rhus radicans* L. and is popularly called poison ivy. In the mountain states there grows the *Rhus diversiloba* Torr. and Gray, which goes by the name of poison oak. A third poisonous species is poison sumac, *Rhus vernix* L. also called swamp sumac, poison ash, poison elder, poison dogwood and thunderwood. This species grows only in bogs and is therefore less accessible than the other two. It forms a tall shrub or even grows into a tree twenty to thirty feet high.

The first two species that we have spoken of, namely poison ivy and poison oak, may be recognized by the characteristic division of the leaf into three leaflets and by the white berries which may remain on the plants well into the winter months and so serve to distinguish them after the leaves have fallen. "Leaflets three, let it be," is a wholesome maxim for those who roam the fields and forests. The plant known as Virginia creeper is often mistaken for poison ivy but may easily be distinguished by the fact that its leaf is divided into five leaflets. Virginia creeper does not cause dermatitis.

Swamp sumac resembles other sumacs in general and has a more complex leaf than the species just described. Its leaf is divided into seven to thirteen leaflets which are three to four inches long and decorated with a large midvein of scarlet color. The berries are white like those of poison ivy.

All three of these species contain a milky juice that is capable of raising blisters on the skin. Some people are more susceptible than others and with them the slightest contact serves to provoke a severe reaction. I do not think that any one is immune. My observation has been that those who are so little susceptible that they may handle the plant with apparent impunity will nevertheless be blistered if the juice of the plant comes in contact with tender skin such as that on the back of the hand or on the forearm. Statements are sometimes made that certain races, like the Indians, are immune to poison ivy. There is no real foundation for these stories. People who are not very susceptible to poison ivy should avoid unnecessary contact with the plant because it is known that susceptibility may be developed by repeated contacts and a previously non-sensitive person may become highly susceptible to the poison and may suffer much discomfort as a result.

Animals do not appear to be poisoned. Whether this fact is due to their protecting fur or to some difference in the structure of the skin is unknown, but they may and do roam through thick patches of the plant without painful consequences. Cattle and sheep eat poison ivy, apparently with impunity, and it may be true that the poison is not irritating to the membranes of the mouth and gastro-intestinal tract. Persons may contract ivy poisoning by handling animals that have gone through clumps of the plant. If you are very sensitive to the poison do not pet a strange dog or cat during your rambles in the country. You may brush ivy poison off the fur onto your hands and transport it to other portions of the body.

Sensitive persons may also be poisoned by handling articles decorated with Japanese lacquer which is made from the juice of a species of *Rhus* that grows in China and Japan. A number of cases of this sort has been reported. However, these articles are safe for any one but the most sensitive to handle. There is a wide-spread belief that a sensitive person may render himself immune at least for the season by eating two or three leaves of poison ivy in the spring. This idea comes from the most diverse sources and apparently has some foundation. It is said that the Indians in the Pacific Coast States were accustomed to resort to this precaution every spring and that they never suffered from the plant. Using this idea a method for immunizing people has been developed by a member of the medical profession and good results are claimed for it.

Of course you are thinking, "Why doesn't some one analyze poison ivy, find out what the poison is and then prepare some antidote for it?" Well, the matter is not so simple as it might seem. Many chemists have made careful studies of these plants and have given us much information concerning them. For poison ivy we have the reports of Pfaff[1] and of Acre and Syme[2]; for poison oak, the report of McNair[3]; and for poison sumac the report of Stevens and Warren[4] and the further report of Warren[5]. Beside these reports there is a large number of others that contribute to our knowledge of the subject.

In spite of the immense amount of chemical investigation performed on these plants the poisonous substance has not yet been isolated with certainty in a pure condition. All these investigators obtained oily substances that were very toxic and that would produce blistering in incredibly small amounts. Pfaff

[1] *J. Exp. Med.*, 2, 184, 1897.

[2] *Am. Chem. J.*, 36, 301, 1906.

[3] *J. Am. Chem. Soc.*, 43, 159–64, 1921.

[4] *Am. J. Pharm.*, 79, 499–522, 1907.

[5] *Pharm. J.*, 83, 562–4, 531–2, 1909.

named it "toxicodendrol" and it appears to be present in all species of *Rhus* that can cause dermatitis. All parts of the plant contain this substance. The green berries are poisonous, but the ripe ones do not appear to contain enough to cause blistering. Toxicodendrol is a complex substance that belongs to the group of compounds called phenols by the chemist. This group contains other members that are capable of blistering the skin but none that are so active as this from poison ivy. Since toxicodendrol is soluble in fats in readily penetrates to the lower layers of the human skin where it sets up the painful irritation so well known to its victims. In this connection it is of interest that a patent has been granted for a blistering lotion, the active ingredient of which is toxicodendrol (U. S. 1,559,340).

We are in possession of sufficient knowledge about poison ivy to be able to recommend measures by which people may escape its effects. Every one who is likely to come in contact with the plant should learn to recognize it and should avoid it. Excellent pictures of the three common species are available in Farmers' Bulletin 1,166, issued by the U. S. Department of Agriculture, a copy of which may be obtained gratis by writing to the department. Just ask for Farmers' Bulletin 1,166, or for the bulletin on poison ivy. This bulletin contains, beside the pictures mentioned, a great deal of valuable information concerning poison ivy, poison oak and poison sumac and should be read by every one who is sensitive to these plants.

When poison ivy grows in locations where it is difficult to avoid it, such as along paths, by roadsides, in the garden or near the house, the plant should be eradicated. This may best be accomplished by digging it up by the roots, but other methods are possible for those who do not wish to get so close to such a pest. These are fully described in the Farmers' Bulletin referred to above, and any one interested in eradicating poison ivy should consult that publication.

If a person has accidentally come into contact with poison ivy or the other poisonous species he may get rid of the poison by prompt and thorough washing of the exposed parts with hot water and soap. It is advisable that sensitive persons take this precaution after every excursion into the great outdoors, whether actual contact has happened or not. Sensitive persons may be forced for business or scientific reasons to walk through areas where these plants abound, and some measure of protection is desirable in such cases. The following precautions have been recommended: Dr. McNair suggests that the hands and arms be bathed in a solution of chloride of iron, 10 per cent., made up in equal parts of glycerin and water, before the sensitive person ventures into the ivy areas. Another preventive suggested is to bathe the exposed parts of the skin with a 5 per cent. solution of copperas or ferrous sulphate before visiting an infested place. One should always remember that in the majority of cases it is the hands that come in contact with the plant, getting covered with the poison, which is then carried to any other part of the body which the hands may happen to touch. If one suspects that he has touched poison ivy with the hands he should be careful not to spread the poison by rubbing his face or arms or touching any other portion of the body until he has thoroughly washed off the poison.

When one has become poisoned the event makes itself known by the appearance of numbers of small blisters that itch painfully or by reddish blotches and wheals. The irritation tempts one to scratch and this serves to spread the poison and at the same time to break the surface of the skin and to allow the poison ready access to the lower layers. A large number of remedies has been proposed for this condition. Many of these are successful in particular cases. In my own experience I have found that an oxidizing agent is the most rational and most satisfactory treatment. The poison is very susceptible to oxidation and if brought into contact with some substance that readily evolves oxygen will be converted into an inert resin incapable of causing blistering. One of the cheapest, most common and harmless oxidizing agents is potassium permanganate, which may be obtained at any drug store. In a strength of 5 per cent. in water this substance is quite effective and, since it stops the itching almost instantly, gives quick relief. It may be applied as a wash, using a piece of absorbent cotton and dabbing it on the affected spots until the itching stops. Blisters should be opened with a sterile needle to allow the permanganate to come in contact with whatever poison is contained inside them. Potassium permanganate turns brown as it gives up its oxygen and leaves a brown stain on the skin. This should be washed immediately after each application. The stain may be removed slowly by washing with soap and water or more rapidly by washing with a 1 per cent. solution of oxalic acid or of sodium bisulphite or of the hyposulphite solution used in photography to fix negatives and prints. Generally one thorough application of the permanganate is sufficient, but in some cases a repetition becomes necessary. Potassium permanganate is harmless to the most delicate skin, especially if the skin be thoroughly washed after each application. After the itching has been stopped the affected area should be allowed to heal. A soothing and antiseptic ointment or lotion may be applied to assist nature in repairing the injured tissues. This treatment will remedy ivy poisoning but the best practice is to shun the plant and avoid poisoning.

WHY CERTAIN SCHOOL CHILDREN ARE BACKWARD

By Dr. C. W. STILES

MEDICAL DIRECTOR, U. S. PUBLIC HEALTH SERVICE

THERE are many different causes which account for the backwardness of school children. Some of these are easily remedied, others are corrected with difficulty, still others can not be eliminated; some are due to economic conditions in the home or in the city or county, others are chargeable to a lack of cooperation with the board of health or with the board of education; some are due to the parents, still others to the teachers or to the child or to the child's ancestors. Whatever the cause in any given case or school or district, every case of retardation is an economic loss to the taxpayers, and the person at fault who does not cooperate with the child in trying to discover and to remove the underlying cause is not only doing the child a grave injustice but is not playing fairly the game of citizenship and self-government with the taxpayers.

The object of this radio talk is to invite the attention of parents and teachers to an easily remediable condition still widespread in certain parts of our country, more especially in the piney wooded sand-lands of the South, a condition which is a serious handicap to thousands of school children, a millstone around the necks of many teachers, a drag to many schools, and a wasteful factor in our taxes spent on public education.

I have recently returned from a

5,524 mile automobile trip, during which I visited 98 white schools, came in contact with nearly 19,000 school children, of whom not less than 20 per cent. showed signs of this easily curable, easily preventable disease which is a potent factor in the backwardness of school children; in other words, at least one out of every five school children I recorded was handicapped by a condition which at a trifling expense could be very easily removed if there were complete cooperation between the parents, the school authorities, the family physicians and the boards of health; and such cooperation would raise the school standards and educational results of the schools and would make it possible for public taxes allotted to the schools to accomplish better results.

I can easily imagine that some of my listeners may possibly exclaim: "What on earth is this crank trying to put across? What does he wish to sell?" The reply is that I refer to hookworm disease, and I am giving you an idea which you can easily test out for yourselves; one which need not worry you if this malady does not occur in your locality. I claim that this idea is not only justified from a purely humanitarian point of view, but is a sound business proposition from the standpoint of the pocketbook of the family, of the school and of the taxes. Hear my story and then inquire of your state board of health whether hookworms are known to exist in your county.

The schools I visited represent the grades or classes known as the first to the twelfth. Some of the grades were divided into three sections (A, B and C) according to pupils' mentality, scholarship or progress in studies. Section A contained the most advanced, section C the most backward and section B the intermediate pupils of the grade.

If, now, I can show that section B contained a higher percentage of pupils showing hookworm symptoms than was found in section A, and that section C contained a higher proportion than section B, I think you will admit that the idea I advance is worthy of your consideration. Assuming that you wish to consider it, I submit the following details:

A. 26 per cent. of the children in section A showed clinical signs which we find in this disease. In general these were rather light cases.

B. 40 per cent. of the children in section B showed symptoms in harmony with this infection. In general these were somewhat more pronounced cases than those observed in section A.

C. 55 per cent. or more than one half of the children in section C, the lowest section, containing the most backward children, showed the symptoms. In general these were the most severe cases of hookworm disease in the schools.

Notice that the percentages (26, 40 and 55) increased as the pupils' efficiency decreased (from A to B to C) and recall that hookworm disease makes for inefficiency, physical and mental backwardness. In all fairness to the children and to the taxpayers do you not think my proposition is worthy of attention?

Let us now turn to a new plan I propose to improve this condition. First of all let me say that the diagnosis of this disease is made free of charge by the state boards of health and by many local boards of health in the states in which this disease occurs. Accordingly, I am not proposing an increased expense to the schools or to the families.

The children who most require examination and medical treatment for this disease can easily be classified by the teachers, without the aid of a physician, into four groups. The first three groups will contain most of the cases which have had the disease for over a year, while the fourth group will contain the cases of recent infection.

I. In the first group should be classified all children who fail in their school examinations or who otherwise show that they are not keeping step with the progress reasonably expected by the teachers.

II. In the second group should be classified all children who in the opinion of the teachers are "puny," undernourished, underfed or underweight.

III. In the third group should be classified all the girls who are maturing irregularly or slowly.

IV. In the fourth group should be classified all children who have had dew itch or ground itch within a year, especially during the summer vacation.

If the school will collect specimens from these children for microscopic examination by the board of health, the laboratory can easily determine in a few minutes whether or not the individual pupils in these four groups have or have not hookworm disease. Write to your health officer for particulars.

When you receive the report from the board of health show it to the child's parents, who should communicate with the family physician in case the examination is positive, and the child should be treated for hookworm disease. If the report shows that hookworms are not present, you should look for some other cause of your child's condition.

In all probability hookworm disease was introduced into this country by the slaves who were brought from Africa, where it is common among the natives and where it is found also in some of the wild animals, such as the chimpanzee.

Hookworm infection spreads in districts where sanitation is primitive, but good sanitation prevents its spread. If a rural town or county has a mixture of good and of poor sanitation the disease is kept alive among the families living under poor sanitary conditions and may spread to the people, especially the children belonging to families whose homes are provided even with the best sanitation. Some country schools and some country churches with poor sanitation form centers of infection for the entire community. I have known cases among the best educated and the most prominent families of infected counties, in the families of school teachers, of physicians, of lawyers, of clergymen, and in other well-to-do families. I know of a former member of the U. S. Supreme Court and of a very prominent United States senator who years ago had the infection.

Through the altruistic generosity of Mr. John D. Rockefeller, the Southern state boards of health have been able to carry on an intensive campaign against this disease. This has resulted in reducing both the number and the intensity of the cases. But the disease still remains an important factor which should not be ignored.

It is not a difficult matter to discover the causes and methods of prevention of many of our diseases, but even when these are known for a given malady it is often very difficult indeed for the health authorities to induce the people to apply even simple measures to prevent the spread of that malady.

For many years I have argued in favor of controlling hookworm disease, basing my argument chiefly on the harm it does to health. Upon returning from my most recent trip, chiefly through the hookworm counties, I decided on a new plan of argument, namely, to emphasize this disease as one of the causes of backwardness in school children and as an unnecessary and preventable drain on the school tax fund. I hope that those of my listeners who are interested in children, in education, in health, and in taxes will think over the idea I have presented to you.

THE SIZE AND SHAPE OF MOLECULES

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EVIDENCE FOR EXISTENCE OF MOLECULES

CHEMISTS and physicists speculated about the existence of particles of matter for a very long time, and used the idea of the atom and the molecule in their thinking and theorizing, even though there was no very definite evidence for the objective existence of such particles. Within the past fifty years, however, a great mass of rather convincing evidence has been accumulating, which leads to the view that atoms and molecules actually do exist.

If one says that "seeing is believing," there is small chance that one will believe in the existence of atoms and molecules, since they are far too small ever to be seen, even in the most powerful microscope. The smallest particle which can be seen through a microscope clearly enough to be identified as to form and size can not be smaller than about one half the shortest light wavelength to which the human eye is sensitive. This fixes the limit of visibility at a particle of size of about 8/1,000,000 of an inch, or at 0.00002 centimeter, 0.0002 millimeter, 0.2 micron, and 2,000 A°. U. (An Angstrom unit is 1/100,000,000 of a centimeter and is a very convenient unit of length for measuring things as small as atoms and molecules). Now the size of the average atom and molecule is several A°. U. or roughly of the order of a thousand times smaller than the smallest particle visible in the strongest microscope. Necessarily, then, any concepts which we entertain concerning the existence of or the size and shape of molecules are not the result of direct observation but are based on inference.

A few of the arguments for believing in the existence of molecules may now be briefly summarized.

(a) *Diffusion.* If a moth-ball, which consists of the chemical substance naphthalene, is placed on a table in a large room of quiescent air, free from convection currents, not much time will elapse until naphthalene can be smelled in every corner of the room. It would be exceedingly difficult, if not impossible, to explain satisfactorily how this diffusion of the volatile substance could occur on any other basis than that it is simply a case of the escape of molecules (that is, tiny particles) of naphthalene, and a spreading of these molecules in all directions through the air. Such an argument of course does not prove the existence of naphthalene molecules, but it goes a long way toward proving it.

(b) *The Radiometer.* Every one who has looked into a jeweler's shop window has seen the little radiometers which spin around in sunlight. The explanation of this effect takes us back to an experiment performed by Benjamin Franklin when he was living in Philadelphia. One morning after a new-fallen snow, when the warm sunlight was beginning to melt the snow, Franklin went into his back yard and spread out two pieces of cloth, one black and the other white. He observed that the snow melted much more rapidly under the black cloth and concluded that a black surface absorbs sunlight more readily than a similar white surface. Exactly the same principle is involved in our choice of white or light-colored clothes for wear in hot summer weather and in the tropics, rather than black or dark clothes. The same principle enters also into our consideration of the radiometer. The radiometer consists of a small spindle which carries 4 vanes, placed 90° apart, and mounted so that the whole will spin (like a top) in a glass bulb from which most of the air has been pumped out. Every vane is polished on one side and blackened with lampblack on the other. When sunlight or any strong light shines on the vanes, the black sides become warmer than the polished sides, and when the air molecules which are moving about quite freely in the partially evacuated glass bulb strike the warmer side of a vane they acquire a greater velocity of motion and jump away more violently than they do from the polished side. because of this temperature difference. The recoil is sufficient to make the spindle turn. Here, also, it would be very difficult to imagine how this spinning of the radiometer vanes could be set up, if we did not have such things as air molecules.

(c) *Law of Multiple Proportions.* There are many known cases in which one element has the power of combining chemically with another element in different proportions. For example, nitrogen reacts with oxygen to form a series of compounds, the composition of which the chemist indicates as : N_2O, N_2O_2,[1] N_2O_3, N_2O_4, N_2O_5; meaning that 2 atoms of nitrogen are combined in the first compound with 1 atom of oxygen, secondly with 2 atoms of oxygen, etc. There is no question about the fact of such combination in different proportions by weight, and it seems extraordinarily difficult, if not quite impossible, to account for this situation, except by assuming that real atoms do exist.

(d) *Spinthariscope.* A spinthariscope is a little instrument consisting of a zinc sulfide screen near which is mounted a bit of radium. If the screen is observed in a dark room it appears to glow, like a radium-treated watch dial. If one looks at the glow through a magnifying lens one sees millions of tiny, but discrete, flashes of light. These are undoubtedly produced by impact on the screen of the alpha-particles during disintegration of the radium. The alpha-particles are positively charged helium atoms. Seeing the separate flashes produced by impact of individual particles is almost as good as seeing the atoms themselves. It is difficult for any one to look into a spinthariscope and not believe in the actual existence of atoms and molecules. Indeed, Rutherford and Boltwood calculated the *number* of helium atoms in a given volume of gas by actually counting the flashes in a modified spinthariscope.

(e) *Brownian Motion.* If we observe, through a microscope, some dust motes or small droplets of tobacco smoke which are floating in quiet air, we notice that they are dancing about, back and forth, up and down, in and out, with a restless, haphazard sort of motion. This motion, named for an English botanist Brown, who discovered it about 100 years ago, can be explained satisfactorily only by assuming that the suspending medium, in which the motes or droplets are floating, is made up of molecules. These molecules are themselves possessed of a chaotic motion by virtue of their temperature energy, and in the course of their ceaseless thermal agitation they continuously bump into the floating dust motes and jostle them about. This observed Brownian motion is very convincing evidence for the existence of molecules.

Finally, by way of concluding the foregoing brief summary of a small part of the evidence in favor of the existence of molecules, we should, perhaps, point out that the weight of no one of the arguments is completely overwhelming. But taken all together, along with the other arguments that can be marshalled, they are sufficient to convince most minds, even sceptical minds, that matter has a fine-grained particle structure. At least we can certainly claim that matter behaves most decidedly as though it is in reality made up of atoms and molecules.

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[1] This is really NO, but for present purposes the formula may be written as given.

EVIDENCE AS TO THE SIZE AND SHAPE OF MOLECULES

A good many years ago Lord Kelvin gave a rough scale representation of a water molecule, in order to help us visualize its size. He said that if a drop of water were magnified to the size of the earth, every molecule would have a size somewhere between that of a buckshot and a cricket ball. To-day we can define the minimum and maximum limits of size much more narrowly, and in the case of the water molecule and a great many other molecules we know the dimensions of the molecule and the distances between the centers of the atoms in the cluster of atoms which constitutes the molecule, with considerable exactness. In Lord Kelvin's day it was customary to think of a molecule as a sphere—a tiny "billiard ball." At the present time our knowledge of molecules is so much more detailed that we are quite sure that, although the *atoms* generally do show a spherical symmetry to most of our probes and tests, the *molecules,* especially the molecules of organic substances, seldom appear to be spheres. They have characteristic skeletal shapes of their own, and in fact appear to be shaped very much as the structural formulas of the organic chemist would indicate. Such structural formulas have been worked out, of course, by purely chemical means.

Let us now consider what the physical evidence has to say about the dimensions and spatial configurations of these invisible particles of matter. We shall be able to discuss only a few of the methods that have been developed for gathering this evidence. One of the most powerful of these methods is the x-ray analysis.

I. *X-ray Analysis.* If one holds a piece of mica, which has a laminated structure, so that a beam of monochromatic light, say yellow light, is reflected from the flat mica surface into the eye, one can see a set of alternate black and yellow lines on the mica. This is an "interference pattern." The yellow light is partly reflected from the top layer of the mica, but some of it penetrates and is reflected from the next lower layer, etc., deep down into mica. As the reflected rays come up out of the mica on the way to the eye they fall on top of one another, sometimes in phase and sometimes out of step, depending on the angle of reflection. Hence the striped effect is produced on the mica surface.

The spacing of the black and yellow lines depends for one thing on the distance between the mica layers. One can easily see that the spacing changes when the mica layers are pushed closer together by finger pressure. In fact, if the wave-length of the light is known, as well as the diffraction pattern spacing, the actual distance between the layers can be calculated by using a very simple equation.

In the same way, if a beam of x-rays is reflected from the face of a crystal, for example, of copper, an interference pattern is developed. In the case of x-rays, however, the pattern is not visible but can be caught on a photographic plate, substituted for the eye. From the nature of the interference pattern one can calculate, if the x-ray wavelength is known, the distance between layers of atoms in the copper crystal. Then by letting the x-rays impinge on other faces of the crystal, the spacing of a whole set of intersecting planes of atoms can be determined, and hence the positions of the atoms located very exactly. The distance between two neighbor atoms is thus obtainable. It is found that the atoms in a copper crystal are piled together in a space lattice in the same arrangement used by many grocers in piling up pyramids of oranges in their store windows, an arrangement known to the crystallographer as "face-centered cubic."

The above extremely crude explanation of the x-ray method may serve to give the reader a rough idea of the underlying principle. This method of investigation has been applied to the study of a large number of crystals, and as a result a great deal of progress has been made in the correlation of physical properties such as density, crystalline form, hardness, ductility, etc., with internal structure of the crystal. Liquids and gases are now also being examined by x-rays by a number of investigators, and these studies are especially fruitful in yielding information regarding the distance between atoms within the molecule.

One of the most interesting crystal lattices (which has been worked out by W. H. and W. L. Bragg[3]) is that of the diamond. The model of this lattice is shown in Fig 1. The balls represent carbon atoms. Every ball is surrounded symmetrically in space by 4 other balls, placed at the corners of a regular tetrahedron. This arrangement, repeated over and over again, gives the entire lattice. The angles between the bonds holding the atoms together are tetrahedral angles, namely, about 109.5°.

It will be noted that the horizontal layers of carbon atoms are "puckered" or corrugated. The arrangement in graphite is quite different. There the layers are flat with all the carbon atoms of a layer in one plane. The atoms in these planes are packed more closely together than in diamond, and the layers are also spaced somewhat farther apart. The slippery, greasy property of graphite is due to the ability of these flat layers to glide over one another. In diamond, however, the spacing of the atom planes is the same in all directions, and there is no tendency for the lattice to flow in one direction rather than in another when it is subjected to stress.

This model (Fig. 1) is made to scale, with 1 inch representing 1 A°. U. The distance between centers of adjacent balls is 1.54 inches, corresponding to a distance in the actual lattice of 1.54 A°. U. If the carbon atoms are spheres, they would have an effective diameter of 1.54 A°. U.

An inspection of the diamond lattice model will show the presence of hexagonal rings, as at ABCDEF. It has been suggested that the benzene ring of the organic chemist has its carbon atoms arranged in the same manner as the diamond ring, which, as can be seen, is a sort of "puckered" ring, with 3 of its atoms in one plane and 3 in another. However, a recent study by Mrs. Lonsdale of the crystal hexamethyl benzene indicates that the benzene ring, in that case, at least, is flat with all 6 carbon atoms in one plane, as in the graphite ring. A model of the hexamethyl benzene molecule is shown in Fig. 2. It seems possible, therefore, that benzene itself may be more properly represented as a flat carbon ring, as in the model of Fig. 3, which also represents 6 hydrogen atoms attached to the graphite ring. This question of the structure of the benzene ring is, however, not yet settled.

Enough has probably now been said to indicate the power of the x-ray method, even in its present state of development, as a tool in our search for evidence regarding the dimensions of and the shapes of molecules.

II. *Oil Films.* Let us now turn to another type of evidence. It is well known that if gasoline or kerosene or paraffin oil, or in general any other mineral oil, is placed on a water surface, it will spread fairly readily to give a pool or lens of oil. If, however, a vegetable or animal oil, such as castor oil, peanut oil, cotton seed oil, sperm oil, or lard oil, etc., is dropped onto a clean surface of water, a film of an entirely different sort is produced. The film is not thick in the middle and tapering out at the edges as in the case of a mineral oil lens, but it is of uniform thickness throughout and if not confined too much it will spread out to give an extremely thin film. This difference in behavior of the two sorts of oil is due to a difference in the nature of their molecules. The molecule of a mineral oil consists of a long chain of carbon atoms with hydrogen atoms attached to every carbon atom in this way,

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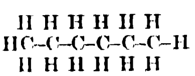
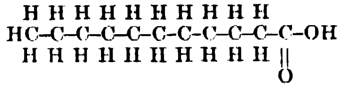
[3] W. H. and W. L. Bragg, *Proc. Roy. Soc.*, 89A: 277, 1914.



$$\begin{array}{c}\text{H H H H H H}\\ \text{HC–C–C–C–C–C–H}\\ \text{H H H H H H}\end{array}$$

Gasoline is made up of a mixture of such hydrocarbon molecules averaging about 7 carbon atoms per chain, although high test gasoline contains molecules with only 5 or 6 carbon atoms. The average kerosene molecules are much longer, of about 11 to 17 carbon atoms, vaseline still longer, paraffin even longer.

None of these materials is soluble in water, and so when such an oil is poured on water, we would expect the oil molecules to be piled together in a haphazard way on the surface like so many sticks of wood. But the vegetable and animal oils have molecules which differ, in general, from mineral oil molecules in one important respect. They, too, consist of long carbon chains, but attached to one end of the chain are some oxygen atoms as shown in the following formula:



$$\begin{array}{l}\text{ H H H H H H H H H H H}\\ \text{HC–C–C–C–C–C–C–C–C–C–C–OH}\\ \text{ H H H H H H H H H H}\ \Vert\\ \qquad\qquad\qquad\qquad\qquad\quad\ \text{O}\end{array}$$

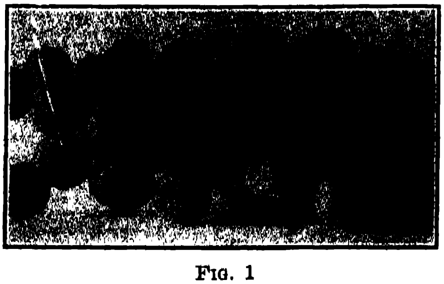


FIG. 1

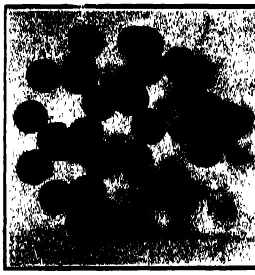


FIG. 2

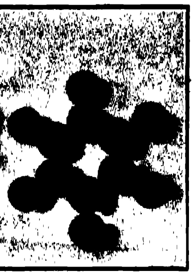


FIG. 3

These oxygen atoms are soluble in water, and they confer solubility on one end of the molecule; but the rest of the carbon-chain molecule remains just as insoluble as ever. As a consequence of this, when vast numbers of these molecules are placed on a water surface, the molecules all stick one end into the water and the rest of the molecule into the air so that they are all standing up on end or are orientated, as in Fig. 4, where we represent the carbon chain by a vertical column and the oxygen bearing group by a black circle. Such a picture of a marshalled array of oil molecules explains why the oil tends to *spread:* every molecule wishes to dip its soluble head under water. Furthermore, for the same reason, the film is one molecule deep; that is, the thickness of the oil film is the length of the carbon chain.

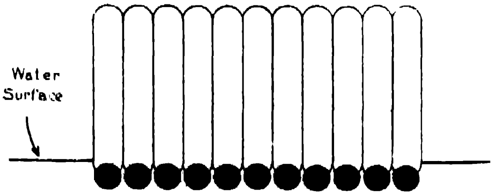


FIG. 4

Dr. Langmuir,[3] of the Research Laboratory of the General Electric Company, who was largely responsible for bringing this previously rather vague and hazy picture of oil film structure to a definite, clear-cut focus, has calculated the dimensions of the oil molecules. This may be done very simply. If we divide the area over which the oil spreads (when the film is pressed together tightly by a lateral pressure at the edge of the film) by the number of molecules in the film, we obtain the cross-sectional area of the molecule as we look down on it from above. If the volume of the film, which may be assumed to be the same as that of the oil before it is dropped onto the water surface, is divided by the area of spread, we get the thickness of the film, or the length of the carbon chain. The results for the stearic acid molecule, which has a chain of 18 carbon atoms and 2 oxygen atoms at the end, give a length of 22 A°. U. and a cross-section of about 5 A°. U. × 5 A°. U., indicating clearly a rod-shaped, or long cylindrical, molecule.

Chemical analysis gives the number of carbon atoms in the molecule. Division of the length of the molecule by the number of carbon atoms in the chain would naturally be considered to give the length of each link, or, in other words, the distance between centers of two adjacent carbon atoms. From a considerable number of measurements of molecules of various lengths, Dr. Langmuir obtained the result that this single link length is about 1.2 A°. U. This result was very surprising, since it is much smaller than the distance between centers of adjacent atoms in the diamond lattice. It hardly seems likely that the carbon atoms in soft, buttery materials like these oil films are packed more closely together than in a hard, dense substance like diamond.

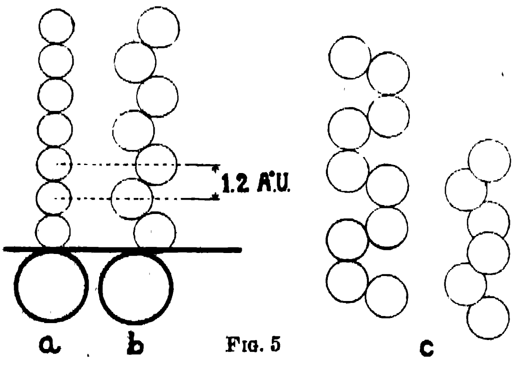


FIG. 5

Dr. Langmuir indicated the way out of the difficulty. What was being measured was not the actual distance between atom centers in the chain molecule, but the *vertical* distance. The molecule chain is not to be represented as at (a) in Fig. 5, but as at (b). The carbon atoms are arranged in a zigzag chain, and if the angles of the zigzag are tetrahedral angles, and the actual distances from center to center 1.54 A°. U., then the vertical distance is about 1.2 A°. U. In the diamond lattice, Fig. 1, one can see a zigzag chain of this sort, namely GFAB.

A few years after Dr. Langmuir's experiments, Müller and Shearer,[4] working in Sir William Bragg's laboratory, showed by x-ray analysis that long hydrocarbon chains could assume various types of zigzag shape, as at (c), Fig. 5, and could even be twisted into a spiral. The angles between the bonds remain tetrahedral throughout, and the variations in shape are produced by mere rotation of the carbon atoms about the bonds, in just exactly the same way that one could stick two oranges, one on one end of a lead pencil, and the other on the other end, and could turn them on the pencil as an axis.

The rubber molecule has been shown to be a long hydrocarbon chain, although somewhat different from those we have just been discussing. Recently

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[3] Langmuir, *Jour. Am. Chem. Soc.*, 39: 1848, 1917.

[4] Müller and Shearer, *Jour. Chem. Soc.*, 123: 3156, 1923.

Dr. Hauser[5] interprets the x-ray diffraction patterns obtained when rubber is stretched and unstretched as meaning that the rubber molecule is coiled up in a helix before stretching, and becomes pulled out during the stretching process.

Thus, one can see how the oil film experiments either alone, or in conjunction with x-ray analysis, have led to a very definite picture of a long stick-shaped hydrocarbon chain, with its carbon links staggered in a zigzag, or wound up in a helix. This picture of a molecule is far different, as far as the *physical* evidence is concerned, from that of Lord Kelvin's day. The idea that one part of a molecule may be different from another part of the same molecule, as in the stearic acid molecule, where one end is soluble in water, and the rest is not, is destined also to play a most important rôle in modern theoretical chemistry, and consequently also in modern practical chemistry. As illustration of the power of this idea let us consider two examples.

1. Stabilization of Emulsions: As we already know, kerosene is insoluble in water. If quantities of kerosene and water are shaken up violently together in a bottle there is formed what we call an emulsion of kerosene in water. Such an emulsion, however, is not stable. The droplets of kerosene soon coalesce and separate from the water into a layer. But if a small bit of soap is present in the bottle while the shaking is going on, the emulsion becomes quite permanent. Now this stability which the emulsion acquires with the soap's assistance may be explained quite convincingly in terms of the same sort of orientation of molecules which we have just employed to account for the spreading of animal and vegetable oils. A molecule of soap is exactly like the molecules of Fig. 4, except that the hydrogen atom in the COOH group at the end of the molecule has been replaced by the atom of some metal, for example sodium or potassium. Now, when soap molecules, let us say of sodium, are mixed with the kerosene and water emulsion the carbon chain part of the soap molecules will stick through the surface into the kerosene droplets, since it is quite a general rule that "like dissolves like." But the COONa is soluble in water and is not soluble in kerosene, so that we would expect to have the convex surfaces of all the little kerosene droplets coated with molecules of sodium soap very much like pins sticking into a pin cushion, as in Fig. 6. Naturally then, since the whole outer surface of the droplet is plastered over with soluble groups we are not surprised to find that the whole droplet has become soluble in water and will remain suspended indefinitely with much less tendency to coalesce with other droplets and form a kerosene layer.

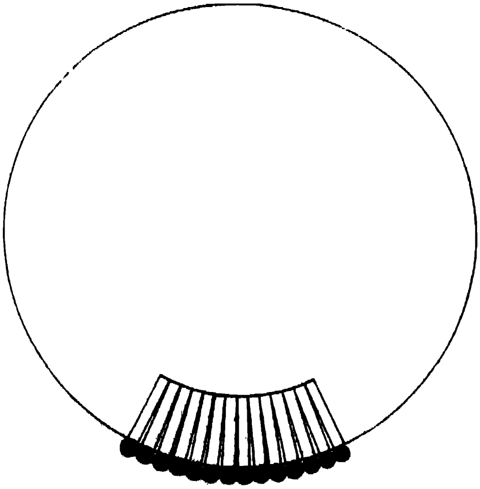

FIG. 6

It is very interesting to note that the detergent action of soap is probably due to exactly this effect we have just described. When we attempt to cleanse our skin, for example, by washing with water alone, the difficulty lies not in washing off "the dirt," but in removing the oil and grease exuded through the pores of the skin or collected on the skin by outside contamination. These oils and greases do not dissolve in water, even in hot water, and it is the function of the soap to emulsify these substances and render them soluble in just exactly the same way as in the case of kerosene.

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[5] Hauser, *Jour. Ind. and Eng. Chem.*, 21: 249, 1929.

2. Lubrication: When a clean metal shaft turns in a clean metal bearing, there is a good deal of friction, and if the two rubbing surfaces are made of the same kind of metal, and especially if the load is a heavy one, a great deal of "seizing" and actual biting of one surface into the other is likely to occur. But if some oil is introduced between the shaft and bearing, the surfaces no longer contact. They turn on the film of oil. The flow has ceased to be "plastic" and has become "viscous." The friction is enormously reduced.

Such an oil film, if it consists of kerosene or vaseline or paraffin, or in general of merely a hydrocarbon, will not serve as a satisfactory lubricant in machines where the frictional load is very heavy. The great pressure will rapidly squeeze the oil out of the bearing. Under these conditions it has been found that vegetable oils such as sperm oil, lard oil, castor oil, etc., are much more efficient. The oxygen bearing groups at the ends of these molecules, the same groups that are soluble in water, groups which have a strong field of force, attach themselves firmly to the metal surfaces, and anchor the oil molecules. To such an extent is castor oil used as a lubricant for the automobiles in the great races at Indianapolis that these races have come to be known as the "castor oil derby."

III. *Collision Areas.* Another promising method of arriving at conclusions regarding the sizes and shapes of molecules involves a determination of their collision areas.

Suppose we have a long capillary glass tube of very small bore, and we let a gas or vapor at a certain observed pressure p_1 flow through the capillary at constant temperature to a region of lower pressure p_2. If, in addition, we know the dimensions of the capillary and the time required for a measured quantity of the gas to flow through, we can obtain the "viscosity" of the gas at the particular temperature. Now, the viscosity of a gas increases with rising temperature, and if we can get the viscosities over a considerable temperature range, we can calculate the collision area of an individual molecule, that is, the target area which it presents to bombardment by its neighbor molecules, as it tumbles through the capillary tube. The application of this method to the experiment determination of collision areas of molecules has been largely developed by the English physicist Rankine.[6]

FIG. 7

If we add saw-dust to a small stream of water, no appreciable slowing up of the flow occurs, but if we add leaves, or twigs, or large pieces of wood, we may set up considerable obstruction to the flow, and in fact even dam up the stream entirely. So also in the capillary tube. The larger the gas molecules, the greater will be the entanglement and rubbing of molecule with molecule, and the greater will be the viscosity, or resistance to flow. This picture may be considered to give, in a crude way, the physical basis of the calculation of the molecule collision area.

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[6] Rankine, *Proc. Phys. Soc.*, 33: 362, 1921; *Proc. Roy. Soc.*, 98A: 360, 1921, and many other papers.

In Table I are listed the collision areas of a number of molecules, determined by several investigators. The areas are expressed in square Angstrom units.

TABLE I

	Collision Areas sq. A°. U.	Shadow Areas sq. inches	
1. Methane, CH_4	7.72	7.6	(Fig. 8)
2. Ethane, C_2H_6	10.6	11.3	
3. Ethylene, C_2H_4	10.3	10.6	
4. Benzene, C_6H_6	19.0	19.2	(Fig. 3)
5. Cyclohexane, C_6H_{12}	21.9	23.2	

The collision area gives a good idea about the size of the molecule, but does not, of course, tell anything about its shape. As far as this experimental result is concerned the molecule could be spherical or stick-shaped or cubical or of any other shape. However, by a special supplementary treatment of the result, it is possible to arrive at interesting and definite conclusions regarding the molecular shape.

Let us make a model, for example, of a methane molecule. We shall make it to scale, one inch for an Angstrom unit. We take a ball out of the diamond model of Fig. 1, and attach to it 4 balls representing hydrogen atoms placed at the 4 corners of a regular tetrahedron. The model is shown in Fig. 8. The effective diameter of the hydrogen atom is taken to be the same as that deduced from x-ray analysis of naphthalene and anthracene, namely about 1.35 A°. U.

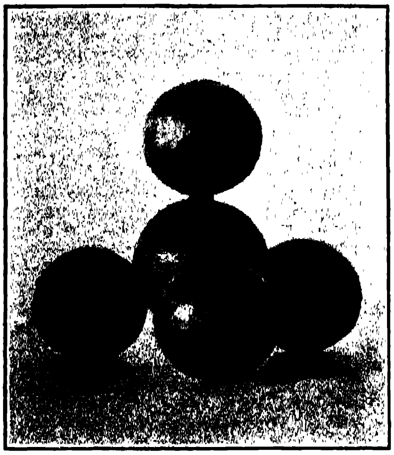


FIG. 8

Now the model is mounted in a support, as shown in Fig. 9, in such a way that its shadow can be thrown on a paper screen. The model, by a motion of rotation, and a dipping, is brought into

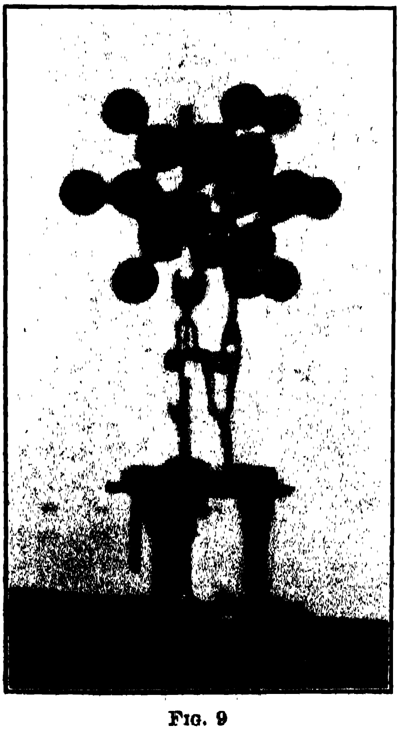


FIG. 9

a large number of different positions so that its average shadow area, or average cross-sectional area can be determined. This is done by drawing the outlines of the separate shadow areas with a pencil, and then measuring their areas with a planimeter, adding up all the areas, and dividing by the number of shadows.

If the model is a good one, that is, if it fairly represents the molecule, there should be a good agreement between the average shadow in square inches and the collision area in square A°. U., as determined by the viscosity method. Table I indicates that this agreement is very good indeed in the case of a number of molecules that have been studied. The reader will readily see how such a combination of the shadow method with the collision area results can be used to test proposed molecular models of various shapes. The method promises to be especially useful in determining the spatial configuration of large skeletal groups in complex organic molecules.

There are many other methods which have been employed to gather evidence regarding molecular size, such as liquid density measurements, and determination of the quantity "b" in van der Waals' equation of state; and also regarding both size and shape, such as dielectric constant and infra-red absorption measurements.

This brief article may serve to convince the reader that we are able to draw certain definite quantitative conclusions, which seem to be consistent and justifiable, about the sizes and shapes of the invisible molecules. These studies are becoming increasingly important. The size and shape of the molecule undoubtedly play an important part in many chemical and physical and vital processes, such as surface tension, viscosity, adsorption, solubility, rate of solution, permeability, diffusion, heat of fusion, heat of vaporization, rate of chemical reaction, catalysis, enzyme activity, colloid particle building and many other related phenomena.

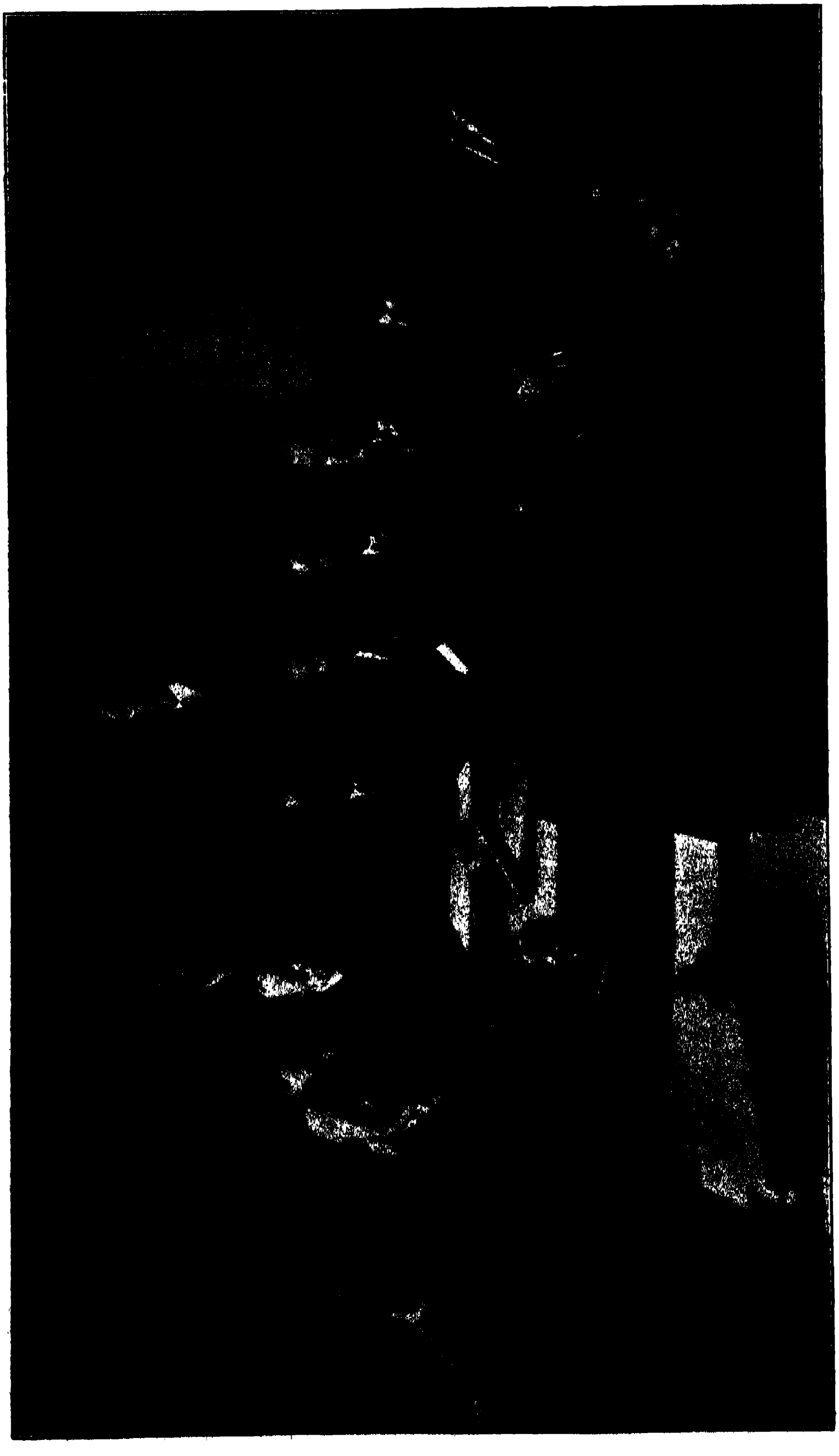
THE PROGRESS OF SCIENCE

THE JUBILEE INTERNATIONAL POLAR YEAR

THE proposed second International or Jubilee Polar Year, 1932–33, is sponsored by the International Meteorological Organization. Following suggestions made in 1875 by Lieutenant Karl Weyprecht, of Austria, this organization also arranged for the first International Polar Year of August, 1882–1883. The immeasurable enhancement in the scientific worth of polar expeditions through pooling of effort in simultaneous physical observations during a full year at many stations in high latitudes over isolated stations occupied even for long periods has been shown by the theoretical and practical applications of some twenty volumes of data obtained during the first International Polar Year. Thus the present magnetic charts of the Arctic are based to a great extent upon this work and the meteorological charts obtained have been the basis of many notable studies in weather-forecasting. The United States took part, together with eleven other countries, in the program of the first Polar Year by establishing two stations (Point Barrow, Alaska, and Fort Conger, Ellesmere Island) in a total of fourteen to twelve in the Arctic and two in the Antarctic.

Founded in 1872, the International Meteorological Organization, consisting of directors of national meteorological and geophysical institutions, has been for sixty years of world service in coordinating national efforts for practical applications of meteorology, in the preparation of improved magnetic charts, and in the development of upper-air observations now becoming so essential to modern meteorology and to air-transportation. At Copenhagen, Denmark, September, 1929, the organization, with official representatives from thirty-four countries present, unanimously adopted a resolution emphasizing the need for a second International Polar Year.

Geophysical sciences have made such rapid progress in the present century and so many new problems demanding solution have arisen that pooling of international resources now must yield much greater scientific and practical profit than realized fifty years ago. Instruments and methods of observing and recording have greatly improved. The practical and economic value of further studies of the magnetic and electric fields of the earth, particularly in its higher atmosphere, which can best be observed under the unique conditions prevailing near the magnetic poles, have been indicated through the definite relations both progressive and irregular changes in these fields have with upper-air conditions and through the correlations of their variations with solar changes affecting both wired and wireless transmission and reception. The interaction of air-masses of different origins and properties and the effect of these interactions on the weather, the circulation of the atmosphere in high and low latitudes, variations in the ozone layer, and many other problems will find increased understanding through simultaneous world-wide endeavor for meteorology, even though the period set is but a year. Such endeavor, perhaps in a lesser degree, must, however, yield useful data in geology and geography through the magnetic and earth-current work at many stations on the structure of the earth's crust and the delineation of new geographical features and perhaps of geo-



MEETING OF POLAR COMMISSION AT LENINGRAD, U. S. S. R., AUGUST, 1930

Magnetic Section, left to right: Rose, Tanakadate, Obolensky, Schokalsky, Khuzechwili, Keränen, Laursen, Harradon, Maurain, Fleming, la Cour, Weinberg.

graphical features as modified in the past fifty years.

The development of the program has been entrusted by the International Meteorological Organization to its International Polar Year Commission for 1932–33. Dr. D. la Cour, director of the Danish Meteorological Institute, is president of this commission, which has two representatives from the United States in a total of thirteen (Captain N. H. Heck, of the United States Coast and Geodetic Survey, and J. A. Fleming, of the Carnegie Institution of Washington). The cost of the preliminary work and publications has been borne by the International Meteorological Organization and by the Danish Government. The first printed report of the commission[1] covers the transactions of its meeting held at Leningrad in August, 1930, and includes a history of the effort and its organization, resolutions adopted for the guidance of the work, and appendices giving in detail reports and recommendations regarding schemes of observation in various fields, equipment and general plans for observatories and quarters. Subsequent circular reports and letters (to be printed in later reports) deal with instructions for each field of observation, development of special photographic equipment, methods and style of publication, etc. The commission's attitude to systematically prepare for the utmost profit in the most economical use of the opportunity and funds is reflected throughout these.

The program proposed recommends establishing forty-three stations in the Arctic region, while in the Antarctic region—so much more difficult of access—it is proposed to establish at least five stations in addition to the permanent one now operated by the Argentine Government in the South Orkneys. Twenty-six nations have thus far indicated that either their governments or their national academies of science may participate by organizing special stations or by intensifying programs of observation at their existing stations. Twenty-one of the Arctic stations and two of the Antarctic stations have been assured already. Additional stations other than those recommended, which may possibly take part in all or part of the program, are on the west coast of Greenland under the direction of Professor Hobbs, of the University of Michigan, near the most northerly part of Greenland by a Danish expedition, and stations on Canary Islands by Spain, on Fernando Poo Island by Spain, and on Easter Island (Pacific Ocean) by Chile. About fifty-five regular magnetic and electric observatories located at various parts of the temperate and torrid zones will participate. Thus the program proposed involves over one hundred widely distributed stations in all parts of the world.

The commission has asked that, if possible, the United States participate by occupying (1) a station in Alaska at or near Fairbanks to take the place of Point Barrow and (2) the station of 1882–83 at Fort Conger in Ellesmere Island. After careful scrutiny and study of the statements submitted in writing in November, 1930, to the United States Department of State by Professor A. E. Kennelly and the writer, the secretary recommended on February 9, 1931, an appropriation of $30,000 for an observatory and necessary instruments and for pay and transportation of personnel to establish the station near Fairbanks. President Hoover favorably endorsed this recommendation in a special message to Congress on February 10, 1931. The

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[1] Premier rapport de la Commission Internationale de l'Année Polaire 1932–1933. Leyde, Secrétariat de l'Organisation Météorologique Internationale, No. 6, iv + 152 (1930).

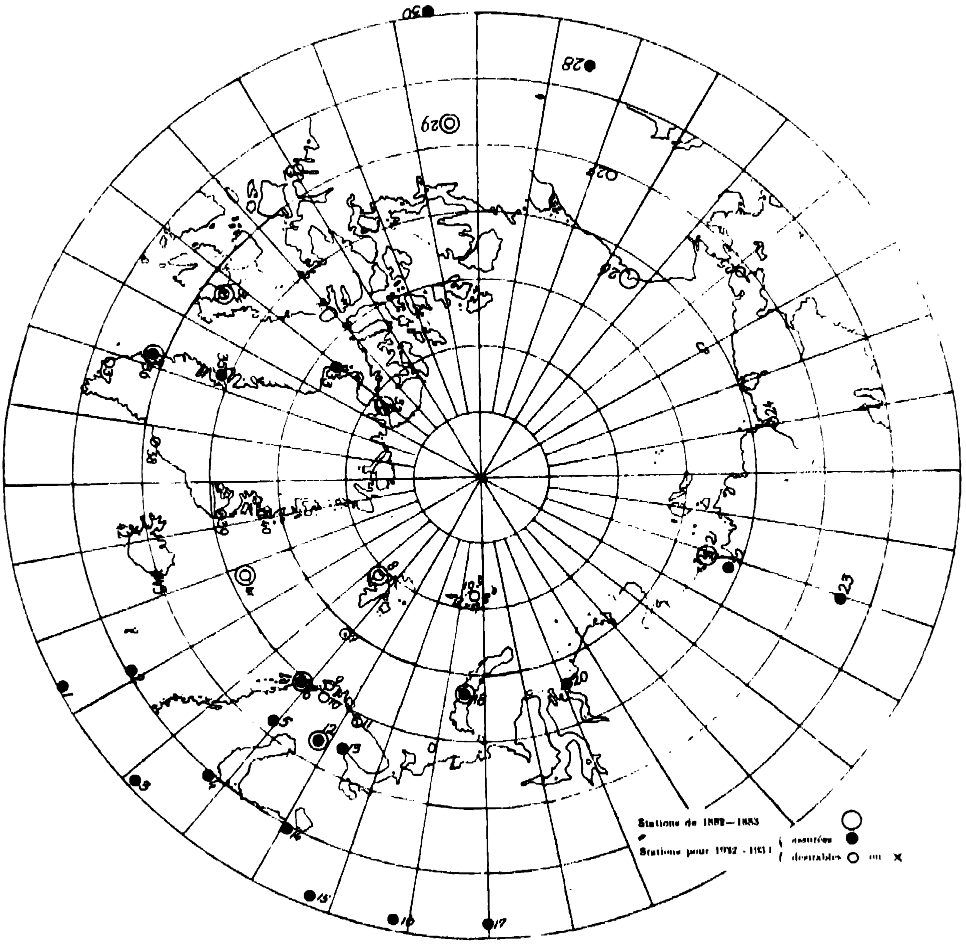


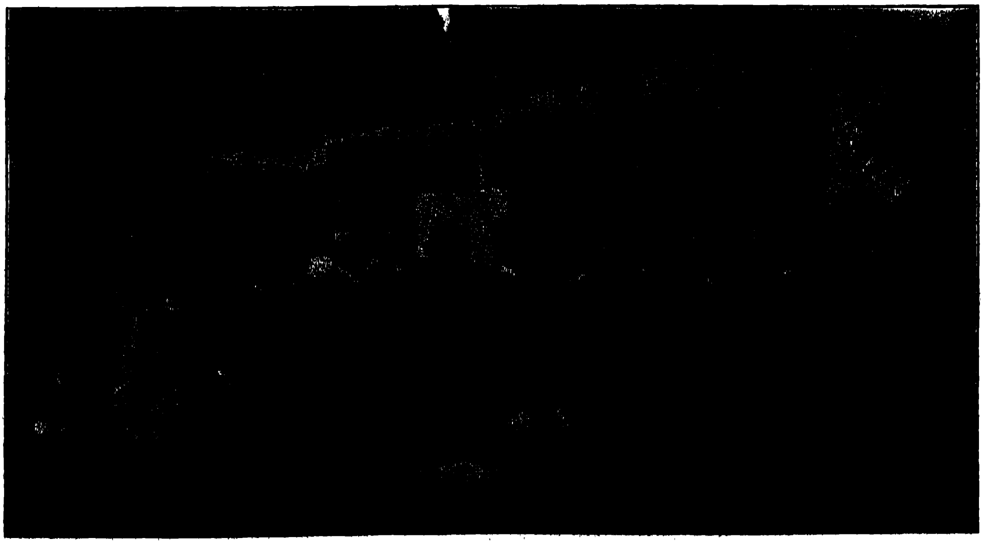
CHART SHOWING PROPOSED STATIONS ABOVE 55° NORTH LATITUDE

1, Eskdalemuir; 2, Lerwick; 3, Rude Skov; 4, Lovö; 5, Abisko; 6, Bossekop-Tromsø; 7, Bear Island; 8, Cape Thorsden; 9, Hammerfest; 10, Kautokeino; 11, Petsamo; 12, Sodankylä; 13, Kandalakscha; 14, Sloutzk; 15, Koutchino; 16, Kazan; 17, Sverdlovsk; 18, Matotschkin Schar; 19, Hooker Island; 20, Dickson; 21, Mouth of the Lena River; 22, Bouloun; 23, Yakutsk; 24, Nijni Kolymsk; 25, Yellen (East Cape); 26, Point Barrow; 27, Fairbanks; 28, Sitka; 29, Fort Rae; 30, Meanook; 31, Chesterfield; 32, Fort Conger (Lady Franklin Bay); 33, Cape York (Thule); 34, Kingua Fiord; 35, Godhavn; 36, Godthaab; 37, Ivigtut; 38, Angmagssalik; 39, Scoresby Sound; 40, Myggbukta; 41, Jan Mayen Island; 42, Reykjavik; 43, Seydisfiord. The Antarctic stations proposed include: New Year's Island; Orcadas, South Orkneys; Kerguelen Island; Macquarie Island; Cape Adare or Little America; Tristan da Cunha.

appropriation contemplates employment of the personnel some time before the beginning of the Polar Year to insure training and preparation of buildings and equipment as well as after the completion of the field work to compile and publish the results. The Senate passed the proposed bill, but, although the House Committee on Foreign Affairs unanimously reported it favorably, the parliamentary jam at the end of the session prevented its passage by the House. Preparations have been made to have the bill considered as soon as possible in the coming session of Congress. It is hoped that occupation of Fort Conger may be effected through a private American expedition with funds subscribed from various sources.

The proposed program has the unanimous support of the American Geophysical Union and of the International Union of Geodesy and Geophysics, as expressed in resolutions adopted by the former in May, 1930, and by the international body at its Stockholm Assembly in August, 1930, with some 302 delegates representing thirty-six countries in attendance.

That department of our government primarily interested in this work is the Department of Commerce, work of similar kind being done under its auspices by the Coast and Geodetic Survey. Other departments which have a vital interest in the Polar Year program are: The Department of the Navy, through its research laboratory, in the study of magnetic and auroral effects on radio transmission; the War Department, through its signal corps, in the development of radio and meteorological work in Alaska; the Department of the Interior, through its interest in development of resources in the territory of Alaska; the Department of Agriculture, through its weather bureau, in meteorological investigations; the Post Office Department through its air-mail service in the north, and the Department of State in its strengthening of international relations and good-will. There are, besides these governmental departments, many organizations in the



MEETING OF POLAR COMMISSION AT LENINGRAD, U. S. S. R., AUGUST, 1930
METEOROLOGICAL SECTION, LEFT TO RIGHT: KLADO, ARNOLD-ALABJEW, KALITIN, TIMONOFF, SCHOKALSKY, KAMINSKY, HERGESELL, JACKSON, DOMINIK, SIMPSON, SVERDRUP, WANGENHEIM, SCHULEIKIN, MOLTSCHANOW, KARTZEFF, TOLMATCHEW, SOKOLOW.

United States greatly interested, for example, the National Academy of Sciences, the Institute of Radio Engineers, universities interested in geophysics and its applications in geological investigations such as the Massachusetts Institute of Technology, Harvard University, California Institute of Technology, Colorado School of Mines, etc. Commercial organizations interested are represented particularly in the communication field and include, among others, the American Telephone and Telegraph Company, the Western Union and Postal Telegraph companies, and companies engaged in air transportation.

Upon completion of the Polar Year and publication of all the resulting data by individual governments and organizations occupying stations, it is essential that provision be made to coordinate, reduce, compile and tabulate the data under the direction of the International Polar Year Commission. Following publication of results at individual stations, the data should be separated and distributed to internationally known specialists for study and discussion. Reports from these to the commission on discussions and conclusions would permit general coordination of findings giving their true scientific and practical value and insuring their consideration in the broadest aspects. This and the publication and distribution to all governments and organizations taking part will require a considerable fund for computational and clerical assistance to the specialists and adequate publication of results, which will constitute in the largest sense distinctly cooperative and international effort.

J. A. Fleming

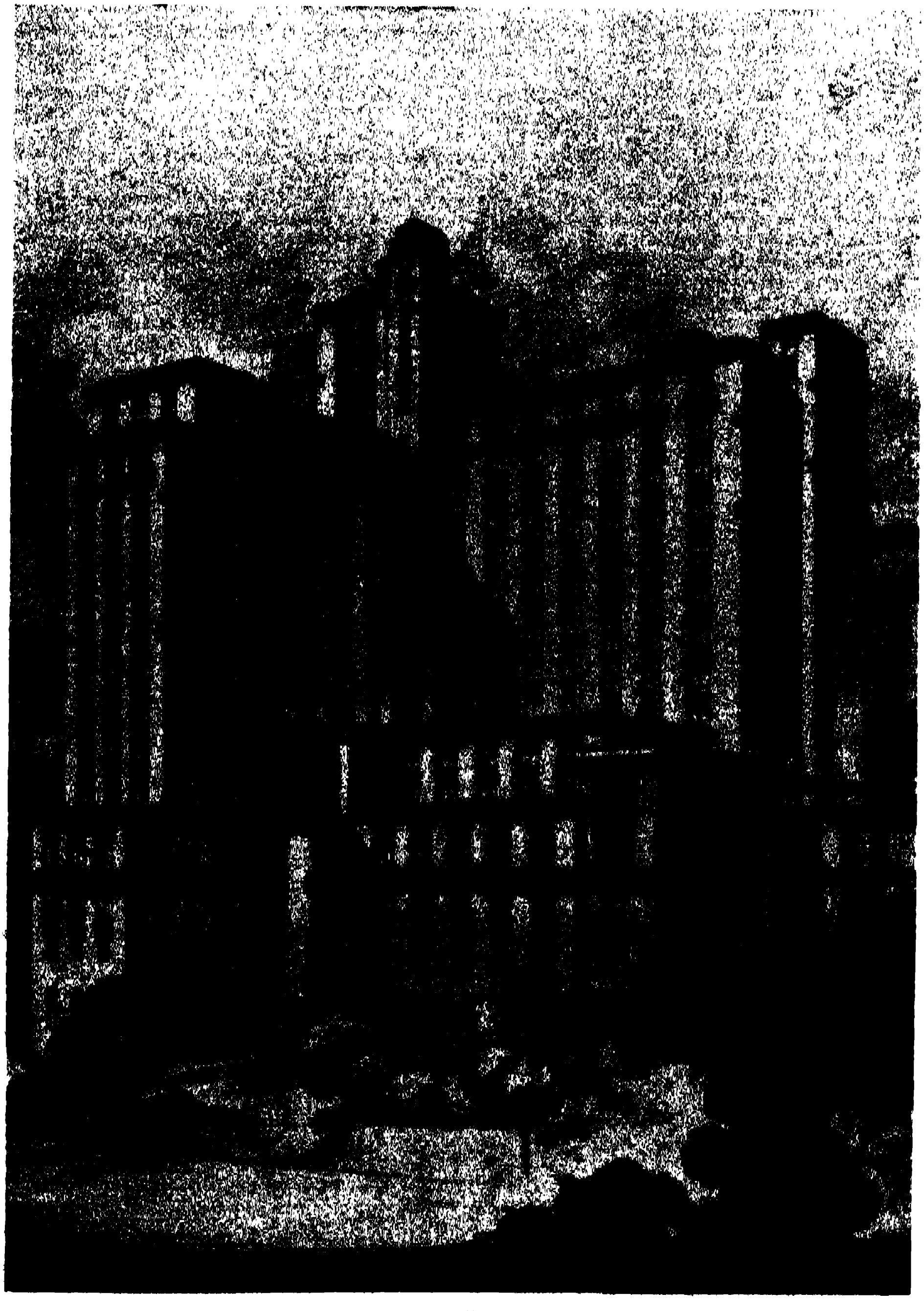
THE NEW RESIDENCE FOR MEDICAL STUDENTS AT COLUMBIA UNIVERSITY

The latest addition to the imposing group of buildings comprising the Columbia University-Presbyterian Hospital Medical Center in the City of New York bears the following inscription:

> This Building is the Gift of
> Edward S. Harkness of New York
> and Named in Honor of
> Samuel Bard
> First Professor of Medicine in King's College
> 1767–1776
> Servant of Columbia College for Forty Years
> as Professor
> As Trustee and as Dean
> of the Faculty of Medicine

Bard Hall, the residence for men medical students and officers of the College of Physicians and Surgeons of Columbia University, is situated on Haven Avenue at 169th Street. The exterior of the building is of light-faced brick with limestone trim, and the design has been kept in harmony with the other buildings of the Medical Center group. The building is erected on the side of a steep hill, the summit of which is 161 feet above the river, which allows for three stories below and fourteen stories above the Haven Avenue level, four of which are in the tower surmounting the building. The windows on the north, west and south façade afford a magnificent and unrestricted view of Riverside Park, the Hudson River and the Palisades.

The two lower stories contain the gymnasium, swimming pool, squash courts and locker rooms. The story below the entrance contains the main dining room, three private dining rooms and ample kitchen and serving facilities. The entrance floor accommodates the lobby, offices and coat rooms, the main lounge and the grill room with loggia and terraces overlooking the river. There are about fifteen bedrooms on the first and second stories in the north wing, which also includes a dormi-



BARD HALL.

tory for students who are on emergency duty in the hospitals. The main bedroom floors comprise the third to tenth stories inclusive and are similar in general arrangement, each including twenty-five bedrooms, four studies, one tutor's suite and a social room, together with conveniently grouped toilets and shower baths. The eleventh story comprises six studies, seven bedrooms, with private baths, and the rooms of the P. and S. Club (Student Y. M. C. A.). The twelfth story contains one apartment, and the two upper tower stories accommodate the machinery room, the fan room and the water tank. All floors are served by two electric elevators.

The bedrooms are of good size, contain clothes closet and lavatory, with hot and cold running water, and are completely furnished. A few rooms have private studies with wood-burning fireplaces. The facilities of the hall include large lounging rooms, dining room, cafeteria and grill rooms, gymnasium, squash courts and swimming pool. Special consideration has been given to the selection of the furniture, rugs, draperies and decoration for the public rooms, tutors' suites, with a view towards comfort, simplicity and harmony.

Each of the tutor's suites consists of a bedroom, bathroom and large living room with a wood-burning fireplace and a well-equipped serving pantry directly connected by electric dumbwaiter to the main kitchen, and the living room is of such size that groups of from twelve to twenty students may gather for discussion before the open fire.

Open roof spaces for rest and recreation are provided on the third floor over the lounge and on the tenth floor opening out from the P. and S. Club, and the building is so planned that should there be demand for more accommodation in the future, it will be possible to erect a wing on the south side of the plot which will provide for 150 additional residents.

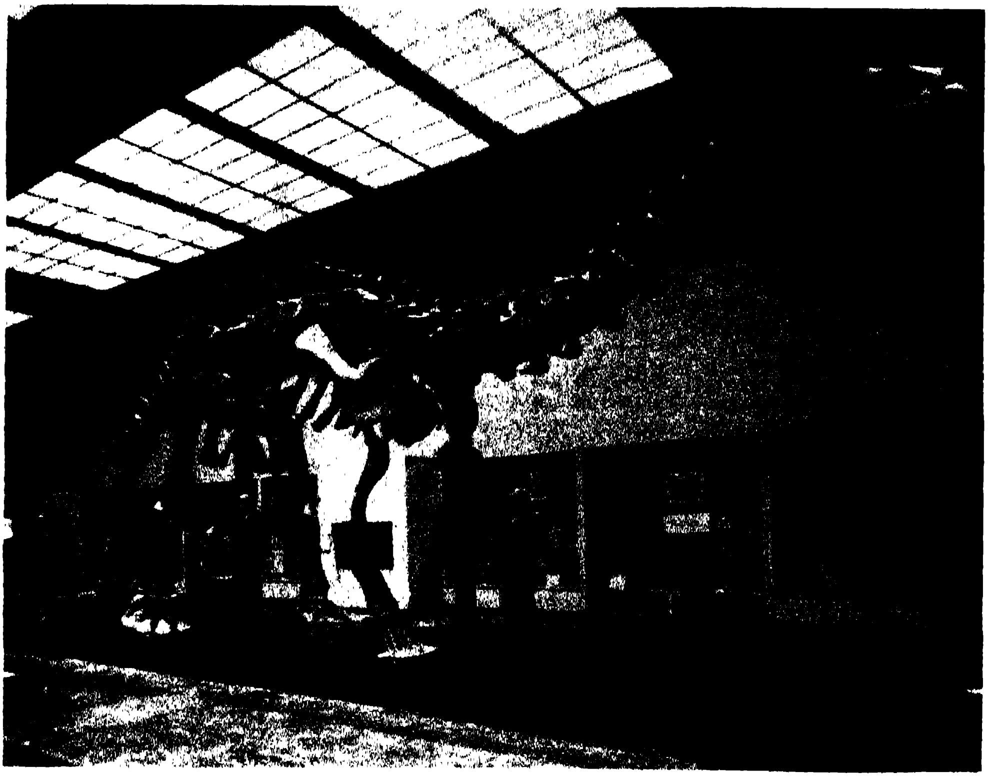
HENRY LEE NORRIS

THE DINOSAUR SKELETON AT THE PEABODY MUSEUM

THE skeleton of *Brontosaurus excelsus* Marsh, recently mounted in the Peabody Museum of Natural History at Yale University, is a most imposing specimen. The bones of this great four-footed herbivorous dinosaur are original, except for the restoration of minor parts, and the skeleton as a whole comprises the most perfect single specimen of this huge form extant. In addition, it is the largest dinosaur so far mounted in any museum. The animal had a length on the curve of the backbone of not less than seventy feet, a height over the hips of about sixteen feet, and an estimated weight of from thirty-seven to forty tons in life.

Fifty years ago this specimen was found in the rocks at Como Bluff, Wyoming, by William H. Reed, a veteran collector for Professor O. C. Marsh. The first box of these bones arrived at the museum on May 20, 1881. The preparation of the skeleton—freeing it from the matrix, piecing together the innumerable parts into which the bones were broken, restoring some of the missing processes, and so on—has taken several years of the most patient and painstaking labor.

This type of dinosaur is characterized by a long neck and tail, with a comparatively short body borne on four ponderous elephantine limbs. The fossilized bones of the animal weigh approximately six tons. This great load is carried on but two uprights, which are borne on a steel grid that touches the floor at only twelve points. The vertebral column lies on an H-beam, bent to fit the curve, and the beam rests on the two uprights. The entire steel



THE DINOSAUR SKELETON AT THE PEABODY MUSEUM.
PROFESSOR R. S. LULL, DIRECTOR OF THE MUSEUM, IS STANDING AT THE LEFT UNDER THE SKELETON.

framework is riveted together to form a solid unit. This method of mounting has not been employed previously for any animal of such great weight.

From the character of the backbone and from the thick pads of cartilage between the bones of the loosely jointed legs it is inferred that dinosaurs of this type spent a considerable part of their times in streams and lakes. However, it is highly probable that they could and did wander over the land on occasion.

The bones in the back of this animal furnish a wonderful illustration of the way in which nature has sometimes attained a maximum of strength with a minimum of weight in that the arches are constructed on the T-iron principle of modern bridge building.

As the head was proportionally very small, with light jaws and spoon-shaped teeth in the front of the mouth only, it is thought that *Brontosaurus* fed on some very abundant and nutritious water plant that flourished in the subtropical climate of the time in which it lived, estimated at approximately a hundred million years ago. The clawed feet were presumably used in uprooting the plants, while the teeth were employed only for pulling them out of the water, and the food was drawn down the throat in large quantities without mastication. The final trituration of the food was carried out by the so-called "stomach stones," contained presumably in a sac, like the gizzard of modern birds. The quantity of food required to maintain these large bodies is calculated to have been at least a half ton each day.

The intelligence of these beasts must have been of a very low order, as it is known that the brain cavity was exceedingly small. An elephant has about nine pounds of brain matter to four tons of total weight, while *Brontosaurus* probably had less than one pound to forty tons. However, the mechanical functions of its body were controlled by the spinal nerve centers, the largest of which, located in the cavity of the backbone in the hip region, may have been many times larger than the brain.

Dinosaurs, to which group *Brontosaurus* belongs, are wholly extinct reptilian animals having no near relatives in the living world. Their kinship on one side is with the birds and on the other, rather less remotely, with the crocodiles and alligators. They were the dominant forms of life during Mesozoic time, and their remains are found in many diverse parts of the world, notably in western North America, Africa and certain parts of Europe. The range of size varied between that of a little fellow about a foot long to that of *Brontosaurus* and probably larger.

Besides these huge plant-feeding dinosaurs there were the carnivorous land forms which attained a length up to twenty feet or more. They progressed on their hind limbs and used their small short fore limbs for seizing and holding their prey. Their jaws were provided with numerous large sharp-edged teeth, usually serrated. Their size, their speed and their sharp claws and teeth made them perhaps the most powerful machines of destruction that nature has produced.

While the dinosaurs of this time were the largest forms of animal life, yet there were many other kinds of beasts. Probably from the present-day standpoint the most interesting were the little warm-blooded mammals which were just beginning to get a foothold, as we know from the bones found in England and North America. In spite of the contrast in size between the two groups—the entire bodies of some of the mammals were no larger than a single tooth of a carnivorous dinosaur—these small forms persisted, while the gigantic dinosaurs vanished and gave rise to the later varied forms of mammals which spread over the entire globe.

In the seas were fish-lizards and other carnivorous marine reptiles whose slender elongated jaws were provided with continuous rows of sharp teeth. Their food consisted mainly of the ganoid fishes which reached their highest development in the Jurassic, of cuttlefishes and probably of sharks. There were very few bony fishes at that time. Crocodiles of the gavial type were quite abundant in the seas and rivers.

About a thousand species of insects were present, together with the first toothed birds, but the flying reptiles, for example, *Pteranodon*, dominated the air. This reptile had a known wing spread up to twenty-two feet. The jaws usually bore numerous long, slender, pointed teeth for holding prey.

The vegetation of those days was far different from to-day, although some of those early forms still exist. There were almost no flowering plants. The bulk of the flora consisted of cycads, rushes, tree ferns and conifers.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1931

MAN AS A PRIMATE

By Dr. ADOLPH H. SCHULTZ

LABORATORY OF PHYSICAL ANTHROPOLOGY, JOHNS HOPKINS UNIVERSITY

INTRODUCTION

IN the classification of mammals the lemurs, monkeys, apes and man are placed in one order, called the primates. This natural group is composed of two rather sharply separated suborders, the prosimians (Prosimiae or Lemuroidea) and the simians (Simiae or Anthropoidea). The former suborder can be divided into a number of families and genera, such as the aye-aye, tarsier, loris, potto, bush-baby, endrina and the various types of lemurs, all of which have become specialized in more or less divergent directions, even though retaining in common many primitive features. The second and more highly developed suborder constitutes a comparatively uniform mammalian group. Since man must unquestionably be assigned to this second division of primates, the suborder of prosimians need not be further discussed in this paper.

According to Elliot,[1] who has written the most comprehensive taxonomic review of the primates, 57 genera and 593 species of recent primates can be distinguished. In this system man occupies but one species and genus. In other words, man represents only one of the nearly six hundred terminal twigs on the family tree of primates, and these twigs spread from fifty-seven branches of which only one is labelled "genus *Homo.*" These six hundred different living primates are the present results of nature's lavish experimentation with one common ancestral stock. In their totality they cover a wide range of variations. This range has become broken up into distinct groups by the extinction of many intermediate forms. The irrefutable reasons for placing man within this range of primate variations are based upon the abundant findings of comparative anatomy, paleontology, embryology, physiology, etc. These findings have conclusively demonstrated that the fundamental similarities between man and at least some of the other primates far outweigh the dissimilarities, and that the latter are frequently no greater, or even much smaller, than the differences existing between other forms of primates.

This is not the place in which to review systematically the enormous bulk of old and recent anatomical evidence which forces us to regard ourselves as near cousins of the apes. This paper is almost entirely restricted to a discussion of some less widely known and mostly quite recent comparative studies on certain features appertaining chiefly to the outer body of primates and to their body proportions. These are the conditions responsible for any "family resemblance" in outer appearance between man and the apes. Only by studying

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[1] D. G. Elliot, "A Review of the Primates" (3 vols.); Monograph I, Amer. Mus. of Nat. Hist., New York, 1913.

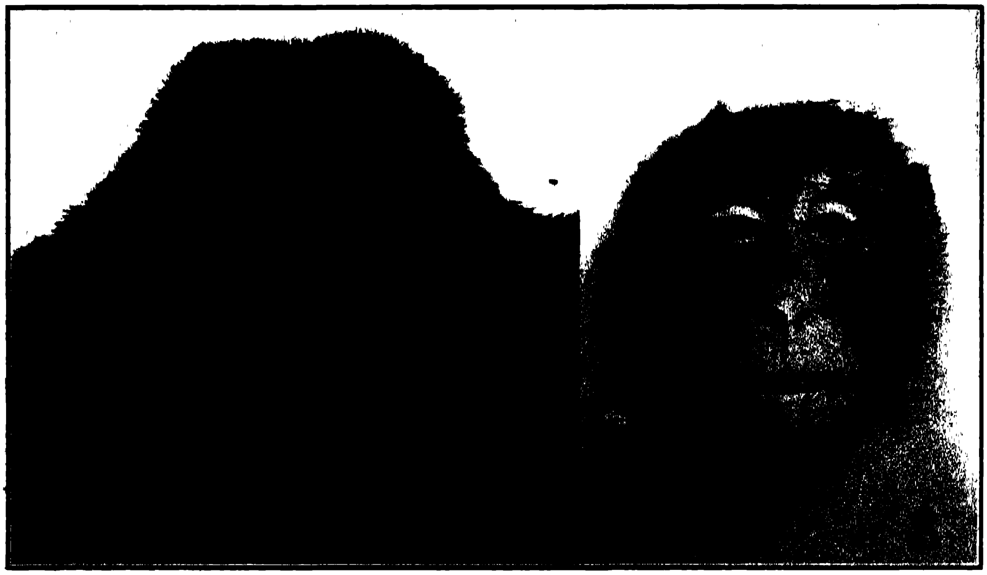

FIG. 1. FRONT VIEWS OF HEADS

A = ADULT MALE HOWLER MONKEY FROM CENTRAL AMERICA; *B* = ADULT MALE PHILIPPINE MACAQUE, SHOWING THE DIFFERENCE IN THE OUTER NOSE.

all the different groups of the Simiae does it become possible to recognize that there exist definite evolutionary trends, which have shaped the bodies of monkeys and man by advancing them in differing degrees along these regular paths, and that in regard to some bodily parts man represents the extreme of the respective trends, whereas in regard to many other parts, one or several of the apes have progressed beyond the stage reached by man. In addition there exists a great variety of detailed trends which clearly deviated here and there from the general evolutionary direction in response to special requirements for one-sided adaptations. By tracing the general trends through all the simian genera the conclusion is inevitably forced upon the investigator that the present form of the human body is merely the best that could so far be accomplished with the inheritance from our precursors, who were adapted to quite different conditions.

CLASSIFICATION

For a proper appreciation of man's position within the suborder of Simiae it is necessary to mention briefly at least a few of the reasons for subdividing this group according to definite distinguishing characters. The first and most fundamental division coincides with the geographical distribution of the suborder. All the aboriginal primates of Central and South America constitute the series Platyrrhinae which differs in many respects from the simians of Africa and Asia which form the series Catarrhinae. The most readily seen difference between these series consists in the formation of the nose. In the platyrrhines (="broad-nosed" monkeys) the nostrils open sidewise and are always separated by a broad septum, whereas in the catarrhines (="narrow-nosed" primates) the nostrils [illegible]ward and have moved so close together that only a narrow septum remains. This is shown by the two examples in

Fig. 1 (see also Fig. 7). There have been found many additional constant differences between American monkeys and the simians of the Old World. Thus, the former possess no outer bony tube leading to the ear drum, whereas in the latter such a tube is formed during growth after birth. Platyrrhines have always three premolar teeth on each side of each jaw, but catarrhines have only two of these teeth. According to these and all other distinguishing features man belongs in the series of Old World primates.

It is of great interest that, in spite of a comparatively uniform environment, the monkey population of tropical America has evolved along a great variety of diverging lines. Two families are recognized: The small and generally primitive marmosets and tamarins (Callithrichidae or Hapalidae) and the larger squirrel monkeys, howler monkeys, spider monkeys, capuchins, etc., known collectively as Cebidae. The former family possesses only two molar teeth on each side of each jaw, whereas in the latter family there are three of these teeth. The elimination of the last molar in the Callitrichidae is undoubtedly a late evolutionary specialization and one which seems to become repeated in spider monkeys, in which the third molars have been found to be congenitally lacking in 15 per cent. of the cases (Fig. 2). Incidentally, a similar evolutionary trend prevails among the higher races of man, in whom the dental arch tends to become shortened at exactly the same place, *i.e.*, by the gradual elimination of the last molar tooth. The Callithrichidae are the only simians which regularly give birth to two or occasionally even three young at a time.

As examples of the marked differences existing within the family Cebidae one may mention the heavy-chested and dull howler monkey which climbs with slow deliberation on top of the branches and the most highly developed of all platyrrhines, the spider monkey, which swings with easy rapidity by its slender elongated arms underneath branches, or runs occasionally on top of a broad limb on all fours, if not on its lower limbs alone.

The catarrhine simians are most properly divided into four distinct families. The least highly developed of these is the family Lasiopygidae (or Cercopithecidae) which includes all the great variety of African and Asiatic monkeys, such as the macaques, baboons, mangabeys, guenons, langurs, guerezas, etc. One of the most readily seen differences between these monkeys of the Old World and those of America exists in the region overlying the ischial tuber-

FIG. 2. UPPER JAWS OF ADULT SPIDER MONKEYS (*Ateles geoffroyi*, EASTERN NICARAGUA)

FROM LEFT TO RIGHT; THIRD MOLAR: OF USUAL LARGE SIZE; REDUCED IN SIZE, NUMBER OF TUBERCLES AND OF ROOTS; CONGENITALLY LACKING ON ONE SIDE; LACKING ON BOTH SIDES.

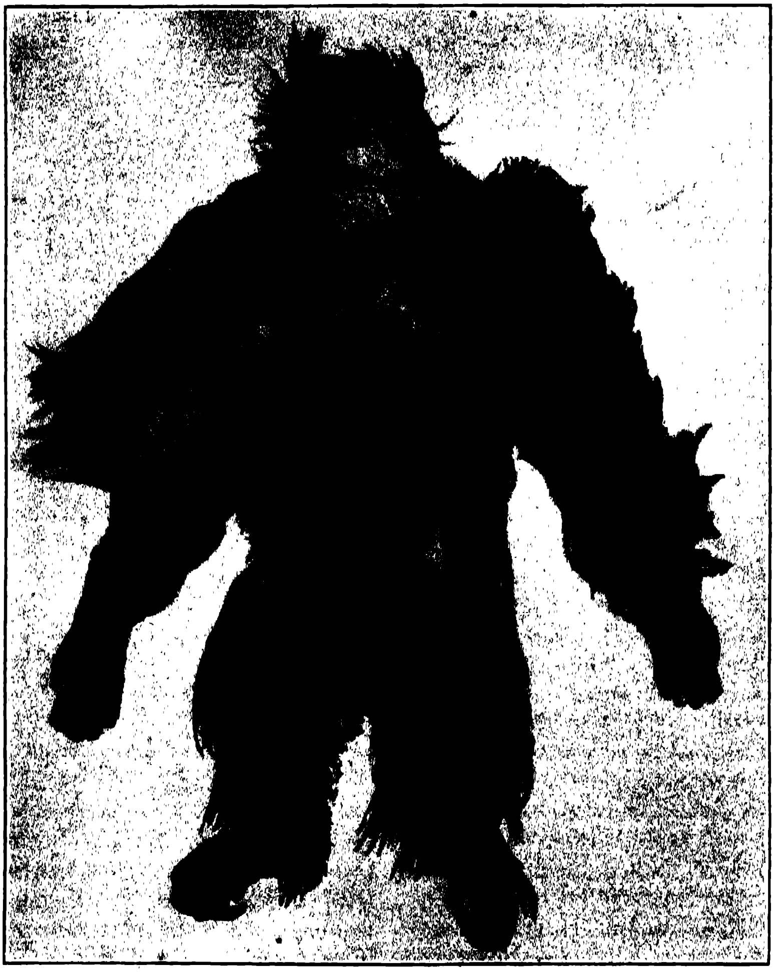

FIG. 3. FRONT VIEW OF AN ADULT MALE ORANG–UTAN, WEIGHING 170 LBS. PHOTOGRAPHED IMMEDIATELY AFTER DEATH (NO. 212, HOPKINS COLLECTION).

osities of the pelvis. In the latter monkeys the skin of this region is as hairy as the rest of the body surface, whereas in the former there are always two large horny zones, the so-called ischial callosities. All these catarrhine monkeys are chiefly quadrupedal forms, with the spine horizontally posed in walking. They are excellently adapted to an arboreal life, only the baboons and a few species of macaques leading a largely terrestrial existence.

The second family, composed of the gibbons and the siamang (Hylobatidae), represents in many respects a transitional stage between the first and third groups of catarrhine primates. These small apes, which apparently have retained many features characteristic of the ancestral stock of all higher primates, have become specialized for the most extreme form of brachiation, *i.e.*, for swinging by their long arms and this with an amazing rapidity and dexterity. No other primate, not even the spider monkey or the orang-utan, is as expert an arm-swinger as is the gibbon. The Hylobatidae, like the lower catar-

FIG. 4. THE FEMALE CHIMPANZEE OF THE ANATOMY DEPARTMENT OF THE JOHNS HOPKINS UNIVERSITY. STANDING UPRIGHT.

rhines, possess ischial callosities, but there exist indications of a gradual process of elimination of these structures among the higher primates. In the lower monkeys callosities appear in early fetal life sooner than the hair; in gibbons they replace the primary coat of hair at the time of birth; and in the siamang they do not develop until during infantile life. In the large anthropoid apes, finally, small ischial callosities are still present in occasional specimens, particularly among some species of chimpanzee.[3]

The third family of catarrhines comprises the three large apes: orang-utan, chimpanzee and gorilla. These are known collectively as Pongidae (or Anthropomorphae) and are sometimes combined with the gibbons as a single family (Simiidae). The Asiatic orang-utan is better adapted to an arboreal life than his two African cousins, of which the gorilla has become mostly terrestrial, at least in adult life. Male

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[3] A. H. Schultz, "Studies on the Growth of Gorilla and of other Higher Primates," *Memoirs of the Carnegie Museum*, XI, 1927.

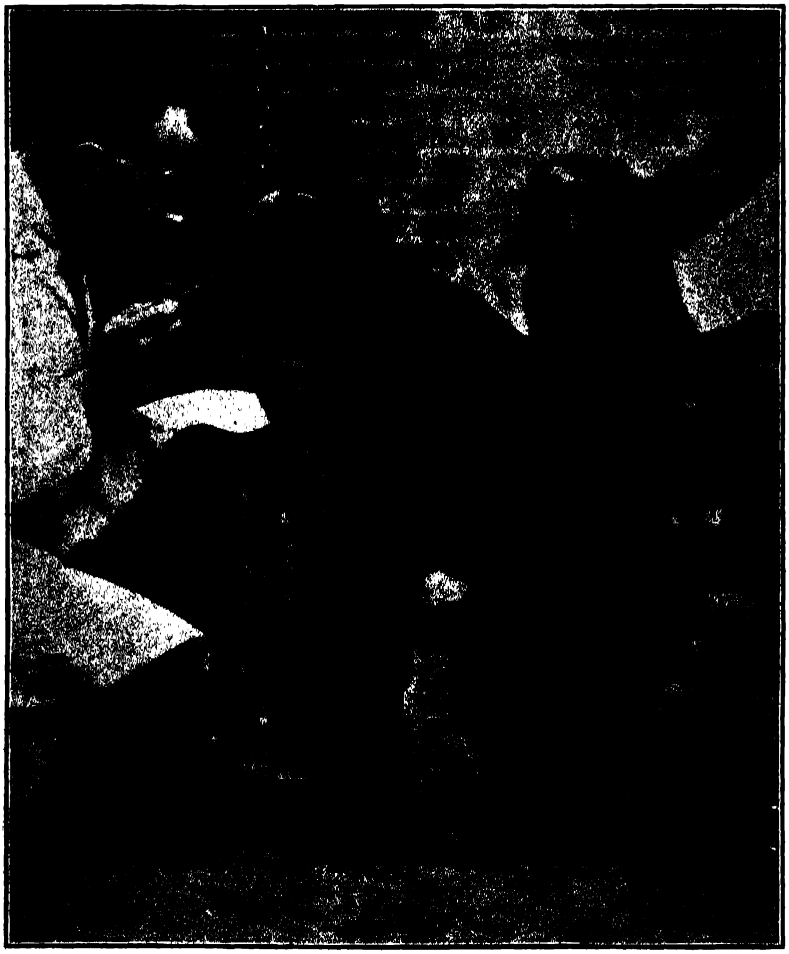

FIG. 5. THE MALE (FOREGROUND) AND THE FEMALE CHIMPANZEE OF THE ANATOMY DEPARTMENT OF THE JOHNS HOPKINS UNIVERSITY. NOTE POSITION OF KNUCKLES IN THE MALE.

orang-utans often develop large cheek callosities (Fig. 3) which occur also in one of the baboons (Drill). They are furthermore characterized by an extensive throat pouch which far exceeds that of the siamang. These are merely two examples in support of the general statement that evolution frequently experiments with the modification of a local structure in a similar manner and simultaneously in several not closely related primates. Another example has already been quoted, namely the tendency to eliminate the last molar teeth in marmosets, spider monkey, and man. Some of the clearest examples consist in the elimination of the thumb in the American spider monkey and again in the African guereza, and in the tendency to reduce the length and number of segments of the tail in a variety of widely separated primates.

The two closely related African anthropoids can walk for short distances in a nearly upright position, but rarely, if ever, are their legs completely straightened in the knee and hip joints (Fig. 4). When walking in their usual quadrupedal fashion these apes (and the orang-utan) hold their fingers bent and rest the weight on the knuckles, as is shown in Fig. 5. In response to this habit the middle segments of the fingers have developed horny layers, which curiously enough are already indicated in the fetus. The chimpanzee swings by its arms more frequently and much more rapidly than does the gorilla.

The fourth and last family (Hominidae) of catarrhine primates has for its single representative man, who has become the only cosmopolitan primate, finding sustenance in all climates. This is one of the reasons for regarding man as the most successful evolutionary experiment among all primates, even though others have become equally well adapted to their—strictly limited—environments. Man's unique specializations consist chiefly in the high development of his central nervous system and in the complete acquisition of the erect posture, which liberated his arms from the function of locomotion and enabled his hands to shape and use tools. Practically all differences between man and the apes can be understood as direct consequences of the two just mentioned specializations.

After these introductory notes some selected data will be presented with which to answer the following closely connected questions: Why must the gibbons and anthropoid apes be regarded as man's nearest relations? What are some of the general evolutionary trends which have produced so many similarities between man and the other most highly developed catarrhine primates? Are the gaps separating man from recent anthropoid apes comparatively large or small when measured by the scale of differences existing between the other primates?

BODY SIZE

In regard to body size adult primates vary within wide limits. Some fully grown marmosets weigh only 9 ounces but some male gorillas more than 400 pounds. As shown by the data for the height of the trunk (from suprasternal notch to pubic symphysis) in Tables I and II, the lowly Callithrichidae, with the trunk height measuring as little as 110 mm, are the smallest simians. The Cebidae range in this dimension up to 290 mm in the highest form, the spider monkey. The lower catarrhines are considerably larger than the great majority of platyrrhine monkeys, reaching their maximum in males of certain baboons and of some langurs. Gibbons have remained comparatively small, rarely exceeding 16 pounds in weight, but the more highly specialized siamang can attain a weight of 28 pounds. Male orang-utans and many chimpanzees equal man in trunk height as well as in body weight, and the gorilla surpasses man in these respects to a very marked degree. There can be no doubt that among primates there prevails a general tendency to increase the size of the body with advance in evolutionary development. The anthropoid apes are the only primates as large as, or even larger than, man.

It may be mentioned here that sex differences in size are not uniform among the primates. In the majority, including man, the males are somewhat larger than the females, but in some types, such as the gorilla and many baboons, the males surpass the females in size enormously, whereas in gibbons, for instance, there exists practically no such difference. In spider monkeys, finally, the average size of males is actually somewhat smaller than that of females.

TAIL

The relatively longest tail among all primates belongs to the American spider monkey. In one such monkey of the author's collection the outer tail measures 847 mm and the spine without the tail only 374 mm. This record tail, therefore, amounts to 226 per cent. of the length of the precaudal spine. The same proportion varies usually between 100 and 200 among American primates, but in the uakari of Brazil this percentage has become reduced to only about 50, this being the only New World primate with a rather short tail. Among catarrhine monkeys the length of the tail has never been found to exceed 175 per cent. of the length of the precaudal spine, and in many forms this index barely reaches 100. In contrast to the platyrrhines, the Asiatic and African monkeys include a considerable number of species with very short or even practically absent tails. With what apparent ease and comparative rapidity the tail can become reduced is indicated by the following data: In an adult Philippine macaque the tail amounts to 135 per cent. of the length of the precaudal spine, but in another species of the same genus, the brown macaque, this percentage has decreased to only 9, and in a specimen of the closely allied Barbary ape to even less than 1! In the latter the fleshy button, representing the last remnant of an outer tail, no longer contains any vertebrae or striated muscles. In the genus of Celebes macaques the tails of several species have become almost as rudimentary as in the Barbary ape.

The tail is most highly developed in the platyrrhine monkeys, among which it can attain a tremendous length and include as many as 34 vertebrae. In a variety of forms the tail has become prehensile and for some distance along its ventral side it bears cutaneous ridges, similar to those on palm and sole. Such tails have assumed the function of a fifth hand, greatly facilitating climbing and enabling the animal actually to hang by its tail. Only one platyrrhine manifests a tendency to reduce its tail.

Among catarrhine monkeys the tail never attained as high a degree of development as in many platyrrhines. It can reach a very considerable length in guenons, guerezas, langurs, etc., but it is never prehensile and serves merely as a balancing rod. In a great variety of catarrhine monkeys the tail has become so much shortened that it must be practically useless; and in several species the tail has almost entirely disappeared from the surface. The number of caudal vertebrae in the latter has become reduced to only 3 to 6 (*e.g.*, Barbary ape and some Celebes macaques).

The gibbons, anthropoid apes and man have in common the complete absence of an outer tail, except in embryonic stages of growth. The number of tail vertebrae varies among these "tailless" primates between 1 and 6. According to the most extensive and recent data this number averages in man 4.2; in chimpanzee 3.3; in gorilla 3.1; in orang-utan 2.8; and in the gibbons 2.7. Man, therefore, has lost his tail less completely than the other higher primates.

HAIR

Man's comparative lack of hair is commonly regarded as a unique condition and as being due to special causes, such as domestication or some form of selection. Recent studies[3] on the density of hair, however, have produced sufficient data to prove that a relative loss of hair has occurred in other higher primates, besides man, and that the human "hairlessness" is largely a matter of degree. Man is the least hairy primate, but in this respect there exist much smaller differences between man and some anthropoid apes than between the latter and the majority of the lower monkeys.

The number of hairs per square centimeter of scalp averages 312 in adult man and can exceed 400 in an occasional white. The corresponding average for five adult anthropoid apes is 282. Catarrhine monkeys have on an average 910 hairs per sq. cm of scalp, some species having as many as 2,000. Among platyrrhines this figure can rise even to above 4,000 and the average obtained is 1,852. The approximate total number of scalp hairs is considerably higher in man than in any of the ten orang-utans and chimpanzees studied.

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[3] A. H. Schultz, "The Density of Hair in Primates," *Human Biology*, III, 1931.

The number of hairs on a sq. cm of skin from the back averages 1,737 in American monkeys, 866 in monkeys of the Old World, 276 in the anthropoid apes, and practically 0 in man. Some platyrrhines have as many as 3,000 hairs and some of the lower catarrhines more than 2,000, whereas in an adult chimpanzee this figure is as low as 48 and in an adult gorilla as low as 109. The total number of hairs on the back is about 100,000 in an adult chimpanzee, but over 1,000,000 in, for instance, an adult guenon monkey. The difference between the nearly complete hairlessness of the human back and the density and total amount of hair on the large back of an anthropoid ape is very much smaller than the difference in these conditions between some anthropoid apes and many of the lower monkeys.

In all monkeys and apes the chest is considerably less hairy than the back. On a square centimeter of skin the chest supports on an average 610 hairs in platyrrhines (over 1,000 in some species), 172 hairs in lower catarrhines (400 in some species), 90 hairs in anthropoid apes (only 21 in an adult chimpanzee and even only 3 to 6 in adult male gorillas), and about 1 hair in man (9 or more in some individuals). The density of hair, therefore, can be greater on the chest of man than on the chest of gorilla. The ranges of variations in the approximate total numbers of chest hairs overlap in man and anthropoid apes.

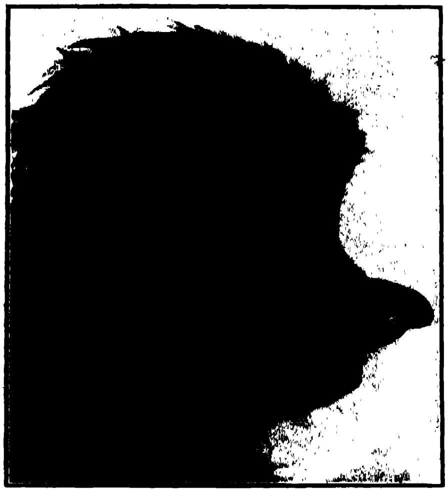

FIG. 6. SIDE VIEW OF THE HEAD OF AN ADULT FEMALE PROBOSCIS MONKEY (NO. 68, HOPKINS COLLECTION).

All these observations indicate very decisively that the extensive loss of hair in man is merely the most extreme manifestation of a general evolutionary trend to reduce the hairy coat of the largest primates.

NOSE

It is a wide-spread popular belief that man differs from monkeys not only in the absence of a tail and the scarcity of hair but also, for instance, in regard to his prominent nose. One glance at the nose of the Bornean proboscis monkey in Fig. 6 should dispel such an idea. This nose of record size represents a specialized new development; it is abundantly vascularized and supported by enormously increased wing portions of the nasal cartilages. The prominent nose of orthognathous human races originated chiefly in an indirect manner through the recession of the alveolary process underneath the nose. In some prognathous races, such as the Hottentots, the nose is hardly more

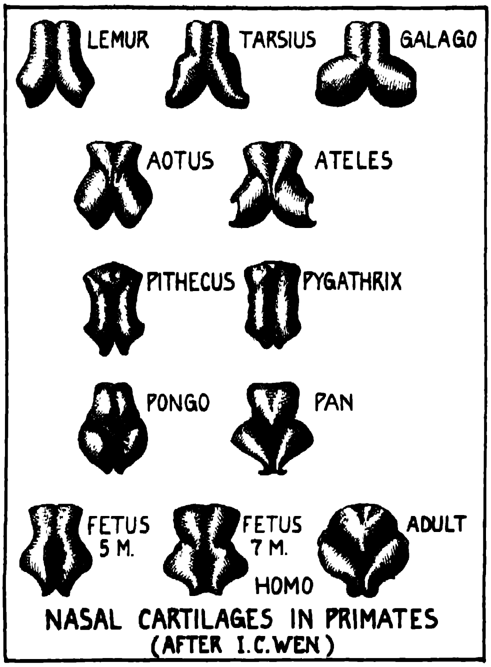

FIG. 7. FRONT VIEWS OF NASAL CARTILAGES IN SOME PRIMATES (AFTER I. C. WEN).

prominent than in some gorillas and at least one species of gibbon.

The shape of the outer nose is to a great extent determined by the size and arrangement of the cartilages within the nose, which extend from the nasal bones down to the nostrils. Fig. 7 illustrates some of the interesting results of a recent extensive investigation[4] of these structures. The top row shows the primitive condition of the nasal cartilages as still existing in prosimians. The two cartilaginous tubes are not yet divided into roof and wing portions. In platyrrhine monkeys such a separation appears for the first time, but is never complete, as shown by two representatives in the second row. A complete division of the primitive tubes into roof and wing cartilages is found only in catarrhine primates (third to fifth row in Fig. 7). Among the latter the conditions in adult man resemble those in orang-utan (Pongo) and chimpanzee (Pan) much more closely than those of the lower forms, as exemplified by Pithecus and Pygathrix. It is readily seen that these cartilages, which are little influenced by any specialized functions, correspond closely to the general classification of primates, as based upon the conditions in so many other structures.

The individual development of the nasal cartilages is most instructive, because it repeats faithfully the evolutionary changes which in all probability have taken place. In man, for instance, there are, during the first half of fetal life, only two undivided tubes, such as persist in a lemur throughout life. Soon afterwards a cleft appears on the lateral borders, exactly as in an adult platyrrhine (*e.g., Aotus*). Not until shortly before birth are the cartilages of man completely divided; whereas in lower catarrhines this separation becomes complete even only after birth. From these findings alone it could be concluded that early in individual development the nasal cartilages of all primates must be closely alike, and that the various degrees of differentiation appear only in the course of growth, just as they have developed in the slow course of evolution. This constitutes merely one of innumerable examples supporting the so-called recapitulation theory, which claims that during the development of an individual there occur many inherited and passing reappearances of conditions having existed in the ancestors of the species at some (usually longer) period of their growth.

EAR

The outer ears of primates are surprisingly uniform in regard to many

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[4] I. C. Wen, "Ontogeny and Phylogeny of the Nasal Cartilages in Primates," *Contribut. to Embryology,* No. 130, Carnegie Instit. Wash., 1930.

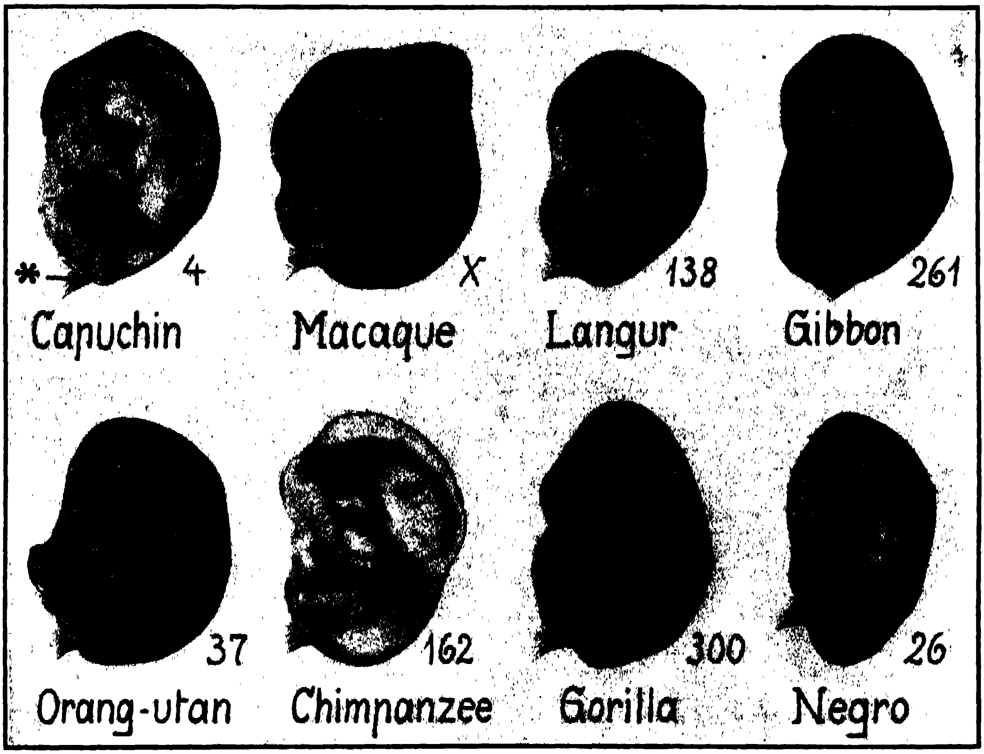

FIG. 8. THE EARS OF SOME PRIMATES (NUMBERS REFER TO CATALOGUE OF HOPKINS COLLECTION)

ALL THE HAIR HAS BEEN REMOVED. * = PLACE OF ATTACHMENT OF EAR TO CHEEK.

features, particularly those appertaining to the portion of the ear by which it is attached to the head. The unattached portion of the ear differs most in the various groups. In macaques, baboons and several other catarrhine monkeys this portion is comparatively flat and drawn into a point (Fig. 8). Among higher primates a strong tendency exists for the free edge of the ear (helix) to become rolled in. This is most pronounced in gibbons, in many orang-utans and gorillas, and in some human races. A true and large ear lobule, free of cartilage, is found only in the majority of human beings and in a considerable percentage of chimpanzees and gorillas. Among all primates the size of the ear has become most reduced in the orang-utan; in a very large male it measures in height only 39 mm. In chimpanzees, on the other hand, the ear is usually of a very conspicuous size, measuring in height 80 mm in one adult female in the Hopkins collection. Gorilla and man possess ears of about the same size (50 to 60 mm) which is intermediate between the two above mentioned extremes.

From these notes and the examples in Fig. 8, it is evident that the human ear resembles most closely that of the gorilla, the differences between the two being insignificant when compared with the differences between the lower and the higher primates.

RELATIVE SIZE OF HEAD

It is a well-known fact that man has by far the largest brain of all primates.

TABLE I

SOME BODY PROPORTIONS IN PRIMATES. THE FIRST 11 SPECIMENS REPRESENT 11 DIFFERENT GENERA OF THE SERIES PLATYRRHINAE (1 TO 3 = FAMILY CALLITHRICHIDAE, 4 TO 11 = FAMILY CEBIDAE). THE FOLLOWING 10 SPECIMENS HAVE BEEN SELECTED FROM 10 DIFFERENT GENERA OF THE LOWEST CATARRHINE FAMILY, LASIOPYGIDAE. THE FAMILY HYLOBATIDAE IS REPRESENTED BY FOUR SPECIES OF GIBBONS AND BY ONE SIAMANG. THE FOUR SPECIMENS MARKED BY AN ASTERISK ARE NOT QUITE FULLY GROWN, ALL THE OTHERS ARE ADULT

Species	Trunk height (mm)	Chest circumfer. / Trunk h.	Chest br. / Chest depth	Arm length / Trunk h.	Leg length / Trunk h.	Arm length / Leg length	Hand br. / Hand l.	Aver. head diameter / Trunk h.
Bald-headed tamarin ♂	110	90.0	95.9	111.7	110.0	101.6	29.8	26.6
True marmoset ♂	124	100.0	94.6	98.4	94.8	103.8	37.8	24.7
Marmoset ♂	159	110.0	93.2	100.2	99.7	100.6	34.8	23.3
Saki ♂	151	94.1	97.5	118.5	115.2	102.8	34.0	29.1
Uakari ♀	236	84.3	98.4	134.7	119.8	112.3	28.7	23.2
Squirrel monkey ♂	205	84.9	96.0	95.6	92.2	103.6	34.6	22.3
Night monkey ♂	191	101.0	92.9	103.3	100.5	102.8	31.4	22.5
Howler ♂	270	144.3	106.6	146.2	117.0	125.0	33.0	26.2
Capuchin ♂	268	106.7	105.0	119.8	115.5	103.2	32.6	24.1
Woolly monkey ♂	265	110.5	103.2	156.1	126.7	123.1	33.0	25.7
Spider monkey ♂	290	120.0	109.4	184.4	135.0	136.4	25.2	24.1
Baboon ♂	412	123.2	86.5	134.4	117.0	114.8	37.8	23.2
Celebes macaque ♂	298	130.4	74.4	145.5	129.5	112.3	33.9	25.2
Tailless macaque ♂	414	118.0	84.6	111.8	100.0	111.8	33.1	21.0
Macaque ♂	346	109.5	87.2	114.0	100.8	113.0	35.6	23.4
Mangabey ♂	296	117.1	78.8	127.7	120.5	105.8	37.2	24.4
Guenon ♂	352	98.9	82.5	100.7	96.5	104.3	34.4	20.8
Red guenon ♀	316	98.7	82.4	107.8	101.8	105.8	31.7	22.2
Langur ♂	357	94.7	90.5	108.0	97.8	110.5	28.8	17.5
Proboscis monkey ♀	353	97.8	103.0	139.5	113.5	122.8	28.6	18.9
Guereza ♀	417	82.7	96.0	103.8	96.9	107.1	31.9	16.5
White-handed gibbon ♂	254	149.5	117.4	251.0	152.7	164.3	20.0	25.6
Borneo gibbon ♀	260	151.5	123.5	239.6	148.3	161.3	25.0	24.7
Wau-Wau gibbon ♂	289	154.6	112.3	225.5	143.8	156.7	31.1	25.2
Sumatra gibbon ♀*	200	148.0	115.5	232.5	146.5	158.6	24.1	33.3
Siamang ♂*	248	160.0	120.5	234.1	131.4	178.1	29.4	29.4
Orang-utan ♀	399	156.8	116.4	204.6	128.6	159.1	30.6	33.3
Orang-utan ♀	440	159.7	120.5	191.7	107.3	178.5	26.3	27.3
Orang-utan ♂	508	190.0	130.0	197.3	116.2	169.5	35.0	25.1
Orang-utan ♂	498	217.8	140.9	204.6	120.8	169.2	37.8	27.2
Chimpanzee ♀	425	155.0	115.1	183.2	136.7	134.0	34.7	26.2
Chimpanzee ♀	478	185.3	124.8	178.3	128.8	138.4	32.2	25.1
Chimpanzee ♂*	464	165.4	133.3	165.7	119.0	139.1	36.5	26.7
Chimpanzee ♂*	463	180.0	122.7	166.6	128.7	129.5	35.9	28.5
Mountain gorilla ♂	687	216.9	144.6	159.6	115.6	137.8	58.1	22.9
Mountain gorilla ♂	723	196.5	146.8	147.8	109.2	135.2	59.0	21.5
Negro ♂	486	163.0	116.8	173.9	191.8	90.7	40.6	31.1
Hawaiian ♂	539	162.6	124.6	133.4	150.7	88.6	40.4	29.1
Chinese ♂	478	158.9	138.2	145.7	165.3	88.1	40.5	33.0
White ♂	494	167.2	115.8	143.3	160.8	89.2	44.9	32.8

In relation to the size of the body, however, many of the smaller monkeys possess a comparatively heavier brain than man.

The relative size of the brain part of the head is most accurately expressed by calculating the percentage relation between the arithmetic mean of head length, breadth and height and the trunk height. According to the averages of this proportion in the last column of Table II, man is characterized by the relatively largest head and the lower catarrhines by the relatively smallest one. In individual cases, however, some of the apes equal or surpass some human beings in this respect (Table I). Thus, in one gibbon and in one orang-utan the average diameter of the head amounts to exactly one third of the height of the trunk, whereas in the Hawaiian to only 29.1 per cent.

In all newborns the head is proportionately much larger than in adults. In human newborns the percentage relation between head diameter and trunk height averages 59. In several newborn gibbons and orang-utans the corresponding figures are even higher (about 61), as has been shown in another paper by the author.[5] For this reason the heads of apes appear more human in early than in late stages of growth. Indeed, many newborn apes have as high a forehead as any adult man, a fact clearly shown by Fig. 9. This high forehead is retained throughout growth in modern man, whereas in the apes it disappears soon after birth in consequence of the insignificant postnatal enlargement of their brains.

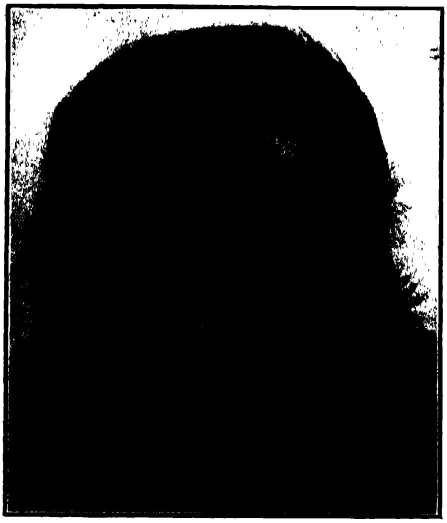

FIG. 9. FRONT VIEW OF HEAD OF NEARLY FULL-TERM FETUS OF AN ORANG-UTAN (NO. 153973, NATIONAL MUSEUM).

TABLE II

AVERAGES OF SOME BODY PROPORTIONS IN PRIMATES, CALCULATED FROM THE FIGURES IN TABLE I

Group of primates	Trunk height (mm)	Chest circumfer. / Trunk h.	Chest br. / Chest depth	Arm length / Trunk h.	Leg length / Trunk h.	Arm length / Leg length	Hand br. / Hand l.	Aver. head diameter / Trunk h.
Platyrrhines	206	104.2	99.3	124.4	111.5	110.5	32.3	24.7
Lower catarrhines	356	107.1	86.6	119.3	107.4	110.8	33.3	21.3
Gibbons	251	150.9	117.2	237.1	147.8	160.2	25.0	27.2
Siamang	248	160.0	120.5	234.1	131.4	178.1	29.4	29.4
Orang-utan	461	181.1	127.0	199.6	118.2	169.1	32.4	28.2
Chimpanzees	458	171.4	124.0	173.5	128.3	135.3	34.8	26.6
Gorilla	705	206.7	145.7	158.7	112.4	136.5	58.6	22.2
Man	499	162.9	123.9	149.1	167.1	89.2	41.6	32.0

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[5] A. H. Schultz, "Fetal Growth of Man and other Primates," *Quarterly Review of Biology,* I, 1926.

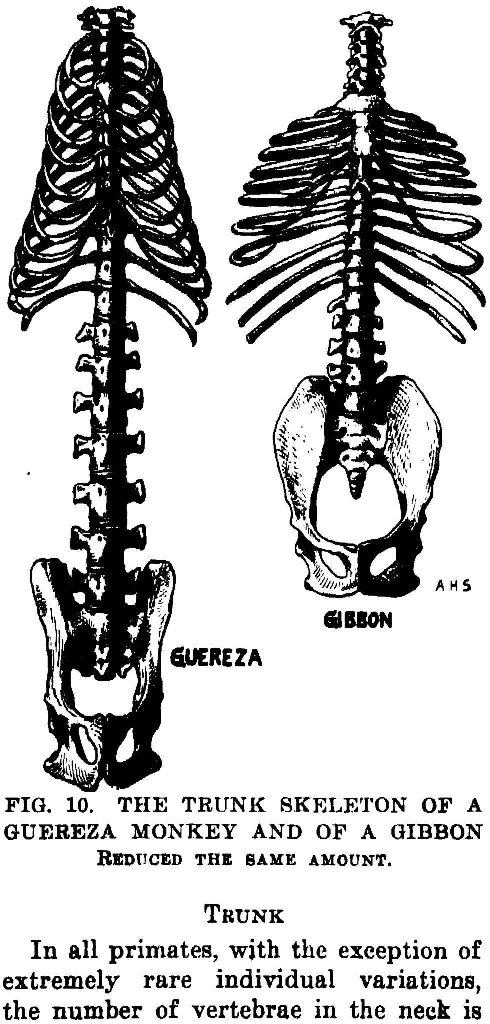

FIG. 10. THE TRUNK SKELETON OF A GUEREZA MONKEY AND OF A GIBBON
REDUCED THE SAME AMOUNT.

TRUNK

In all primates, with the exception of extremely rare individual variations, the number of vertebrae in the neck is 7. In contrast to this, the numbers of vertebrae in the other regions of the spine vary a great deal not only in individuals but also in the different families and genera. This has already been shown in regard to the tail. In the adjoining sacral region a number of vertebrae have fused into one rigid structure by which the spine is fastened to the pelvis. In the monkeys of the New and the Old World the sacrum is usually composed of three vertebrae, two and four occurring only in exceptional cases. In gibbons and siamangs the average number of sacral vertebrae has increased to 4.4, and the range of variations extends from 3 to 6. In anthropoid apes and man the minimum and maximum have again increased, namely to 4 and 7, respectively, and the averages have shifted to above 5. According to the latest figures[6] these averages are higher in chimpanzee (5.4) and gorilla (5.5) than in man (5.2). These notes suffice to demonstrate that with the general advance of primate evolution more and more vertebrae tend to solidify into the sacrum. It is significant that this progressive sacralization of vertebrae has reached an even greater extreme in two of the anthropoid apes than in man.

In the remaining portion of the spine, which comprises the vertebrae of the chest and loins (thoracolumbar vertebrae), a general tendency prevails toward reduction in the number of segments. Among platyrrhine and catarrhine monkeys 19 of these vertebrae are most commonly found. In some platyrrhines (night monkey) there occur even 22 thoracolumbar vertebrae, whereas in the specialized spider monkey the average has become reduced to 17.9, quite a few individuals possessing only 17. As in so many other respects, the gibbons furnish the "missing link" between the lower catarrhines, on one hand, and the anthropoid apes and man, on the other. Their average number of trunk vertebrae amounts to 17.8 and the variations range from 16 to 19. Among the four largest primates, cases with 19 of these vertebrae have completely disappeared; indeed, no case with even 18 vertebrae has ever been recorded for orang-utan. With this elimination of these retarded and primitive numbers the pendulum of variations has begun to swing toward lower and progressive numbers. Only 16 trunk vertebrae occur in about 3 per cent. of human spines and even only 15

[6] A. H. Schultz, "The Skeleton of the Trunk and Limbs of Higher Primates," *Human Biology*, II, 1930.

in an occasional chimpanzee and gorilla (1 to 2 per cent.) and in 15 per cent. of orang-utans. The average number of these vertebrae has become reduced to 17.0 in man and even farther in the large apes, namely to 16.8 in chimpanzee, 16.6 in gorilla and 16 in orang-utan.

In regard to all these features of the spine, man has been found to resemble most closely the anthropoid apes, but in every instance the general evolutionary trend has carried one or several of the latter even beyond the stage reached by the former. These are merely a few of a long list of conditions which reveal man as a rather conservative primate in comparison with his anthropoid cousins.

The trunk of the higher primates has become relatively shortened by means of the gradual elimination of vertebrae, which allowed the pelvis to shift toward the chest (Fig. 10). In addition and probably in direct connection with this evolutionary process, the trunk of the higher primates has become very stout and broad as compared to the trunk of lower primates. This widening of the trunk, involving the width between the shoulders, the diameters of the thorax and of the pelvis, etc., is already very pronounced in the gibbons, as is strikingly shown by Fig. 10. How sharply primates can be divided into those with slender trunks and narrow chests and those with stout trunks and broad chests is best demonstrated by means of accurate measurements and their interrelations. During the past decade the author has carefully measured many hundreds of dead and embalmed monkeys and apes, including practically every group of primates. Not until recently has he been able to study fully adult gorillas in the flesh. This long hoped for opportunity came with the return of the Columbia University-American Museum African Expedition, when the author was generously permitted to study the enormous bodies of the two male mountain gorillas, brought from the Belgian Congo. With this addition it is possible for the first time to give the exact body proportions of adults of all types of higher primates and of most of the lower ones, all measured in a strictly uniform manner.[7] For the present purpose it must suffice to discuss only a few proportions in a small series of specimens, selected to represent the different types of the *Simiae*. These data are listed in Table I, and the averages thereof in Table II.

The degree of stoutness of the trunk is best shown by the percentage relation between the chest circumference (at the

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[7] A. H. Schultz, "The Technique of Measuring the Outer Body of Human Fetuses and of Primates in General," *Contribut. to Embryology*, No. 117, Carnegie Instit. Wash., 1929.

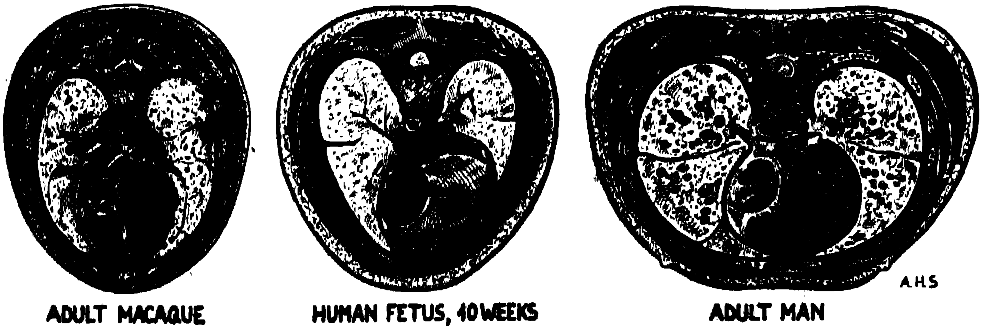


FIG. 11. CROSS SECTIONS THROUGH THE CHEST OF AN ADULT MACAQUE, A HUMAN FETUS AND AN ADULT MAN

ALL REDUCED TO THE SAME CHEST DEPTH.

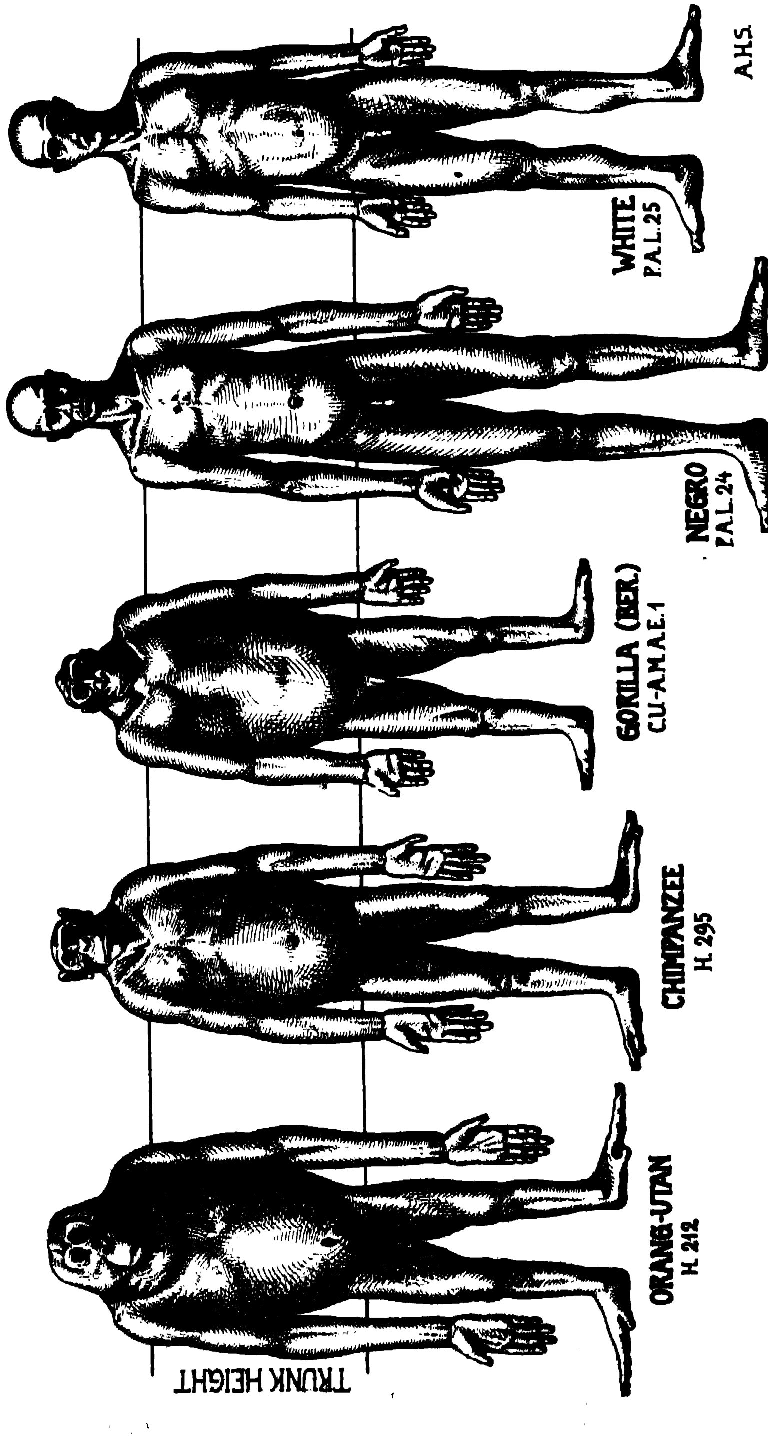


FIG. 12. EXACT SEMI-DIAGRAMMATIC FRONT VIEWS OF THE FOUR LARGEST PRIMATES AT FULLY ADULT AGE

CONSTRUCTED FROM DETAILED MEASUREMENTS ON ACTUAL SPECIMENS, DRAWN WITHOUT THE HAIR, ALL REDUCED TO THE SAME ANTERIOR TRUNK HEIGHT.

level of the fourth pair of ribs) and the height of the trunk (second column of figures in the tables). Among the lower New and Old World primates this index lies frequently below 100, indicating a long and slender trunk. The isolated maximum of 144 is attained by male howler monkeys which possess by far the bulkiest trunk of all platyrrhines. In the gibbons the average of this index has increased to above 150, in man to 163, and in the large apes to even much higher figures. In the gorilla the chest circumference is on an average more than twice as great as the height of the trunk.

In young fetuses of all primates the width of the chest equals approximately the depth of the chest, so that a cross-section appears to be roughly circular. As shown by the examples in Fig. 11, the chest shape of the lower primates changes comparatively little in the course of growth, whereas in man the chest grows much more intensively in width than in depth. The chest shape is accurately expressed by the percentage relation between the chest breadth and the chest depth (third column of figures in the tables). In platyrrhines this index averages about 100, in the lower catarrhines only 87, but in the gibbons it has changed to 117. In man and chimpanzee the transverse chest diameter amounts on an average to 124 per cent. of the sagittal one, in orang-utan to 127 per cent. and in the gorilla even to 146.

These notes on the trunk have shown without exception that the higher primates as a group have become differentiated from the lower ones by a gradual reduction in the number of presacral vertebrae, by a marked widening of the shoulders, chest and pelvis, and by an enormous increase in chest breadth as compared to chest depth. In regard to all these features man falls within the range of variations among gibbons and anthropoid apes; indeed, in a sense he represents the "missing link" between the former and the latter. Again, therefore, we have no choice in assigning man a place among the primates. This place is determined by the striking similarities in the conditions of the trunk between man and the three large apes.

Relative Lengths of the Limbs

The length of the limbs in relation to the height of the trunk varies enormously among primates. Thus, the total length of the arm, from shoulder joint to tip of the longest finger, amounts to only 95 per cent. of the trunk height in a squirrel monkey, but to 251 per cent. in a white-handed gibbon (see fourth column of figures in the tables). The total length of the leg, from great trochanter to sole, in percentage of the trunk height (next column of figures) varies not quite so extensively, the minimum of 92 occurring again in the squirrel monkey and the maximum of 192 being represented by a Negro. These figures alone go to show that the great relative length of the human leg is not as extreme a specialization as the enormous proportionate length of the arm in gibbons.

The total arm length of the great majority of quadrupedal monkeys with a long trunk amounts to anywhere from 100 to 130 per cent. of the trunk height. The typical condition (about 115) is represented by the capuchin among platyrrhines and the common macaque among the lower catarrhines. This percentage can be increased either (to about 145) by shortening the trunk, as in the howler and probably the Celebes macaque, or (to as much as 184) by lengthening the arms in direct response to the habit of swinging by the arms, as in the woolly and spider monkeys. Both these processes have most likely combined in producing the unparalleled

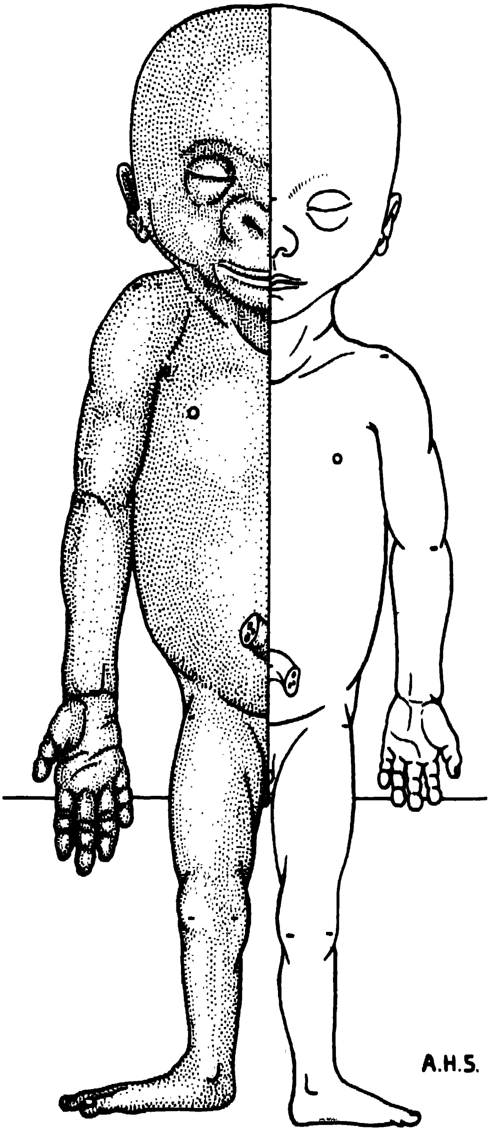


FIG. 13. EXACT BODY PROPORTIONS OF THE FETUS OF A LOWLAND GORILLA (LEFT HALF) AND OF A HUMAN FETUS (WHITE) OF THE SAME STAGE OF DEVELOPMENT (4TH MONTH)

REDUCED TO THE SAME SITTING HEIGHT.

relative arm lengths (192 to 251) of the most extreme brachiators, the gibbon, siamang, and orang-utan. Chimpanzees have also acquired proportionately longer arms (173) than any of the lower primates, except the spider monkey. Some individual chimpanzees, however, can possess relatively shorter arms (166) than some human beings (Negro = 174). The same is found in regard to the East-African or mountain gorilla. The larger specimen of the two measured by the author has a relative arm length of only 148 which practically equals that of a Chinese (146) and lies far below that of the body of a Negro, chosen at random for this study. Fig. 12 illustrates clearly this difference, according to which an ape can have proportionately much shorter arms than a man, a finding which is quite contrary to our previous beliefs.

When this paper was ready for the press the author was generously permitted by Professor William K. Gregory and Doctor Dudley J. Morton to measure also the three splendid bodies of adult male West-African or lowland gorillas, the last specimens to arrive from the recent Columbia University-American Museum African Expedition. Of the many results, gained by this unique opportunity, it is possible to mention here only that a number of striking differences were found between the two types of gorilla. Thus, the relative arm length of the three lowland gorillas amounts to 180.3, 183.1, and 187.5, respectively, *i.e.*, to more than in most chimpanzees, whereas in the mountain gorilla this percentage averages only 153.7. It is particularly significant that in regard to this proportion one species of gorilla (*G. beringei*) stands closer to man than to the other species of gorilla (*G. gorilla*).

The relative length of the leg is shorter than that of the arm in all the primates, except man, but it should be kept in mind that the arm length includes the entire hand, whereas the leg length only a small part of the foot. In all the monkeys and in the anthropoid apes the relative total length of the lower limb varies only between 92 and 137. In the gibbons and man alone has this percentage become increased to higher figures, in the former chiefly in consequence of the shortening of the trunk, whereas in the latter predominatingly through a great lengthening of the limb itself. The striking difference between man and the three large apes in regard to the relative length of the legs is at once apparent in Fig. 12. This difference, however, loses in significance through the following observations. In the white-handed gibbon the relative length of the leg is 153, whereas in the body of a perfectly normal Hawaiian in the Hopkins collection it is only 151. In other words, there are some human beings with a relative leg length no greater than in some gibbons. The difference between the relative leg length of 192 in a Negro and that in the Hawaiian is far greater than the difference which exists in this respect between the latter and all gibbons as well as most chimpanzees. Furthermore, in newborn man the relative length of the lower limb averages only 116, which is roughly the same as in adults of most monkeys. During fetal life man and gorilla have still the same leg length, as is shown by the example in Fig. 13. As the unequaled length of the lower limb of adult man does not appear until late in growth (Fig. 14), it can not have been acquired until comparatively late in evolution.

For a proper interpretation of the significance of the lengths of the limbs they are studied not only in relation to the length of the trunk but also in relation to one another. This latter relation is obtained most accurately by expressing the total arm length in percentage of the total leg length (sixth column of figures in the tables). In platyrrhine as well as catarrhine monkeys this proportion averages 110; *i.e.*, the arm is ten per cent. longer than the

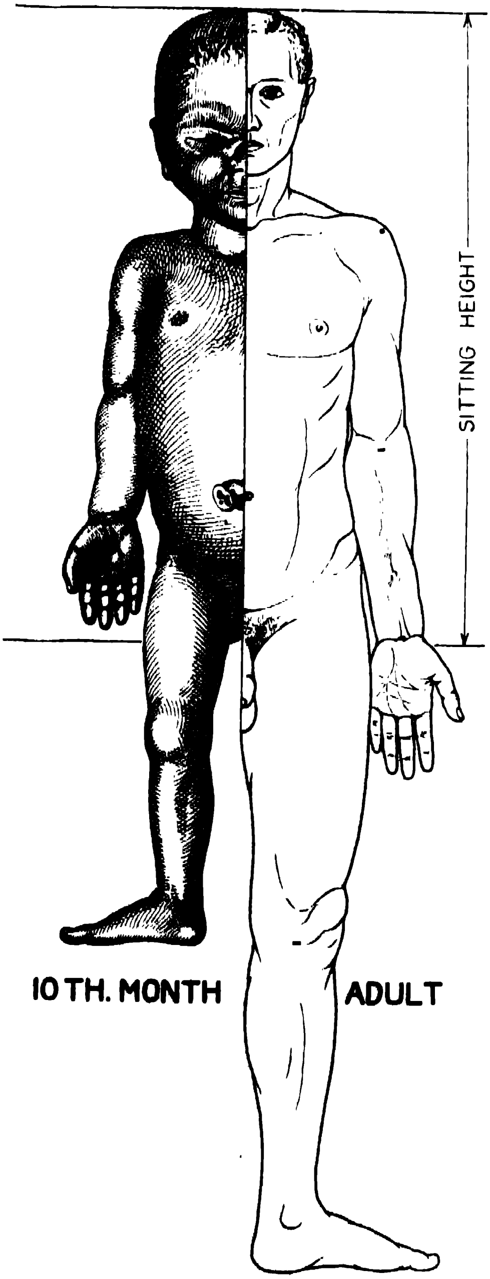


FIG. 14. EXACT BODY PROPORTIONS OF A HUMAN NEWBORN AND OF AN ADULT MAN

BOTH REDUCED TO THE SAME SITTING HEIGHT.

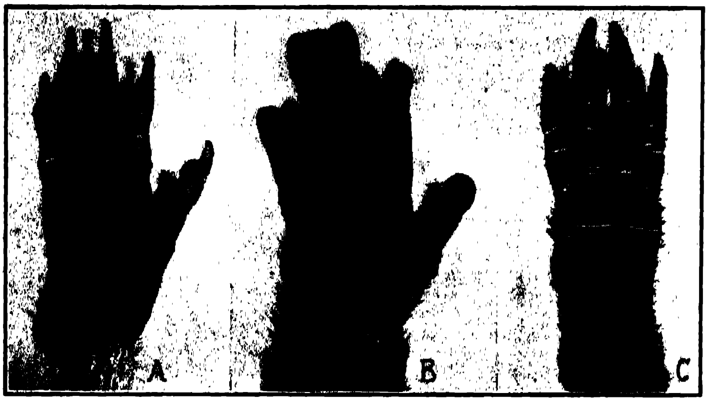


FIG. 15. HANDS OF *A* = MARMOSET (NO. 230); *B* = NIGHT MONKEY (242); *C* = SPIDER MONKEY (248 *a*) (LEFT HAND)
ALL FROM CENTRAL AMERICA.

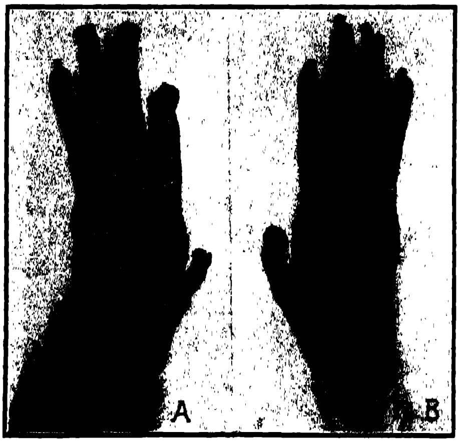


FIG. 16. HANDS OF *A* = LANGUR (180); *B* = PROBOSCIS MONKEY (68).

leg. In all the gibbons and anthropoid apes this percentage has become increased to at least 130, a value which occurs among lower primates only in the extreme brachiator, the spider monkey. The highest of all figures are found in the most expert "hangelers," the gibbons, siamang, and orang-utan, in which the arms have become extremely lengthened as an adaptation to their special mode of locomotion. The lowest of all figures, as was to be expected, are restricted to the most perfect bipedal walker, man, whose legs have become extremely lengthened in connection with his unique type of progression. In newborn man this proportion lies still above 100, as in all adult monkeys and apes, and it is only during postnatal growth that it drops below 100, a unique condition among primates.

From all considerations it seems most likely that the original and as yet little specialized Simiae possessed the following approximate limb proportions: With the trunk height equaling 100 the

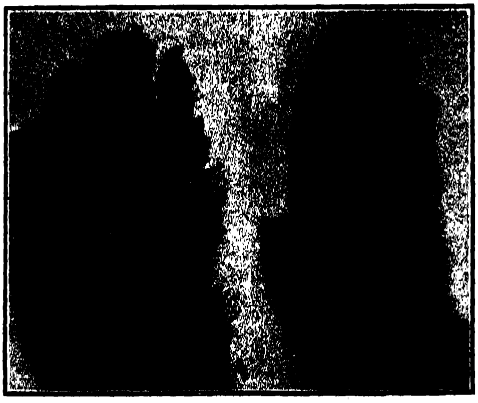


FIG. 17. HANDS OF *A* = BABOON (27); *B* = SIAMANG (NO. 255980, NATIONAL MUSEUM).

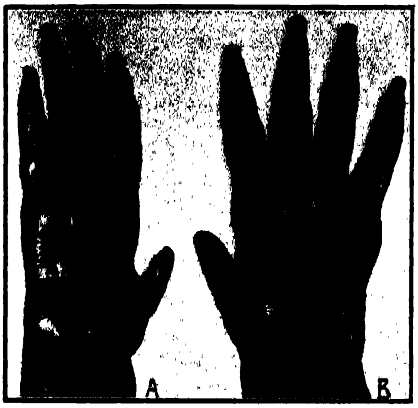


FIG. 18. HANDS OF TWO ORANG-UTANS
A = ADULT MALE (212); *B* = JUVENILE MALE (37). PHOTOGRAPHED FROM PLASTER CASTS BY THE AUTHOR.

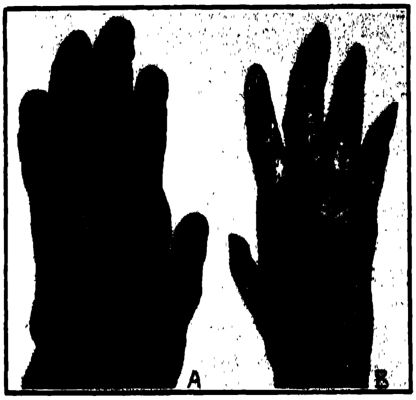


FIG. 19. HANDS OF TWO CHIMPANZEES
A = JUVENILE MALE (163); *B* = ADULT FEMALE (295). PHOTOGRAPHED FROM PLASTER CASTS BY THE AUTHOR.

total arm length was 120, the total leg length 109, and, consequently, the proportion between arm and leg length 110. As shown by Table II, these (hypothetical) values persisted without significant change in most monkeys of the Old and New Worlds. The only noteworthy exceptions are the American woolly monkey and, particularly, the spider monkey in which all three original indices have become markedly increased. This represents an evolutionary experiment among the platyrrhines which has been repeated among catarrhines in a much more extreme manner in the gibbons and orang-utans. This particular trend in primate evolution to increase the relative length of both the upper and the lower limb has been at work not only among the types just mentioned but among all higher catarrhines, including man. These increases are the result of two distinct but cooperating factors: (1) a proportionate shortening of the trunk and (2) a new

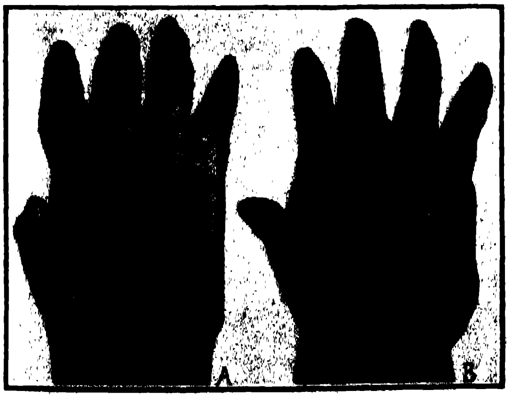


FIG. 20. HANDS OF TWO GORILLAS
A = ADULT MALE LOWLAND GORILLA (CAST BY THE AUTHOR OF SPECIMEN LENT BY MUSEUM OF COMP. ZOOLOGY, HARVARD UNIV.); *B* = ADULT MALE MOUNTAIN GORILLA (CAST SENT BY AMER. MUSEUM OF NATURAL HISTORY).

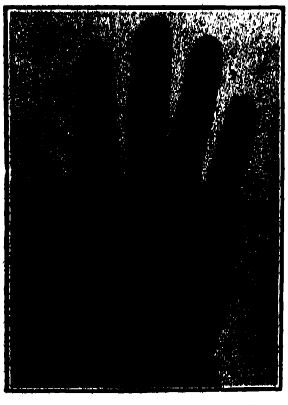


FIG. 21. HAND OF AN ADULT MALE NEGRO (P. A. L. 26)
THUMB UNUSUALLY LONG FOR NEGRO.

and active growth of the limb, stimulated by its particular requirement for specialized locomotion. The relative arm length of man has increased from the original hypothetical 120 to 150, and the relative leg length from the original 109 to 167. The latter increase of 58 index units is not nearly as great as the increase of 117 index units (from 120 to 237) in the relative arm length of the gibbons. Similarly, the percentage relation between the arm and the leg length amounted to approximately 110 in the conservative ancestral Simiae; in adult man it has decreased to 89 or by 21 units; but in the siamang it has become changed much more, having increased to 178, or by 68 units.

It has been shown that the ranges of individual variations in the relative length of the arm overlap in man and the mountain gorilla, and that this character has evolved to much greater extreme in the other apes than in man. The relative length of the leg is greater in man than in the other primates, though individual gibbons can equal some human beings in this respect. Man's evolutionary specialization in leg length has not reached nearly such an extreme as the gibbon's specialization in arm length.

HAND

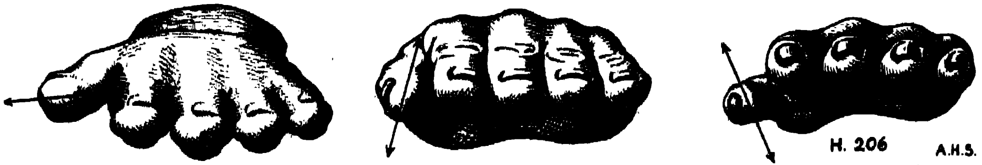
As shown by the accompanying series of photographs (Figs. 15 to 21), the primate hand is a comparatively constant and uniform structure, even though many details have become changed in the higher types according to definite evolutionary trends. In the primitive marmosets (Fig. 15 A) the fingers still bear long and slender claws, rather than nails. In many of the American monkeys the touch pads on the palm are still very conspicuous, as, for instance, in the night monkey (Fig. 15 B). With the exception of the spider monkey, the thumb of platyrrhines is of considerable length, reaching beyond the palm; it is not rotated to face the other digits and, therefore, is not opposable; it always branches from the palm near the base of the index finger. These are all primitive conditions, appearing in the hands of young fetuses of all primates, but persisting to adult life only in the monkeys of the New World. The second finger of all platyrrhines is much shorter than the fourth. As a rule the middle finger is longer than all the others, but in the saki and uakari monkeys the fourth finger has become the longest. In the spider monkey (Fig. 15 C), the most highly specialized platyrrhine, the thumb has become eliminated, except for some vestigial bones hidden within the hand. In only two of a great many spider monkeys, collected by the author, there still exists a small and functionless outer thumb.

In contrast to platyrrhines the thumb of the monkeys of the Old World has become opposable and its place of attachment to the palm has shifted from the base of the index finger toward the wrist (Figs. 16 and 17 A). It never reaches beyond the most distal point of the palm and in such forms as the langurs (Fig. 16 A) and, particularly, the guenons it has become reduced to a practically useless appendage. This evolutionary trend to reduce the thumb has reached its extreme not only in the American spider monkey but again in the African guereza, in which there is rarely any outer thumb left, except during fetal stages of growth. In a few catarrhine monkeys, particularly the largely terrestrial baboons (Fig. 17 A) and macaques, the touchpads are still well developed even in adults. In all lower catarrhines the index finger is shorter than the fourth finger and the latter is nearly as long as the middle digit.

The hand of the higher primates, from gibbon to man, conforms to the type of hand in lower catarrhines by possessing a thumb which has become twisted to oppose the other digits and which branches from the palm at a place near the wrist, thereby further facilitating true opposability. The thumb of the siamang (Fig. 17 B), the orang-utan (Fig. 18), and the chimpanzee (Fig. 19) has shifted farther away from the base of the second digit than has the thumb of gorilla (Fig. 20) and of man (Fig. 21). In none of the siamangs and large apes does the thumb reach to the end of the palm; only in some gibbons can it project that far. Man is the only higher primate and, indeed, the only catarrhine in whom the thumb extends beyond the most distal point on the palm. In regard to this relative length of the thumb man differs strikingly from all three large apes. Yet the short thumb of a chimpanzee, for instance, is still of good use. Many a time the Hopkins chimpanzees have been observed to extract dexterously small splinters in the skin by means of their thumb and index finger. The gibbons, siamang, and man are the only simians in which the second finger can be as long as, or even longer than, the fourth finger, but there are many individuals in which the general rule of "finger IV > II" still holds true.

From the photographs of primate hands it can be seen that gorilla and man have the broadest hands of all primates. This is most conclusively demonstrated by the figures in the second last column of the tables, which express the breadth of the hand in percentage of the length of the hand. Among the monkeys the narrowest hand (relative breadth = 25) is found in the best brachiator, the spider monkey, and the broadest hand (38) in the most terrestrial form, the baboon. Among the highest primates the hand is again relatively narrowest (27) in the most perfect brachiators, the gibbons, and proportionately broadest in the least arboreal forms, man (42) and mountain gorilla (59). In regard to this index gorilla is much farther removed from all other primates than is man. Incidentally, it is well known that the relative breadth of the human hand varies a great deal individually. The author has become convinced from his measurements on very extensive series of other primates that the hands of monkeys and, particularly, apes vary individually and racially at least as much as does the hand of man. This is merely indicated by the examples in figures 18 and 19 and by the data in Table I.

It has been shown that the hand of man is in every respect the hand of a catarrhine primate. That it evolved from a more primitive type of hand, such as persists in platyrrhines, is a necessary conclusion from many observations. For instance, in human fetuses well developed touch pads make a passing re-appearance, the thumb still branches from the base of the second digit and is not yet rotated to face the



HUMAN FETUS, 8WEEKS ADULT MAN ADULT CHIMPANZEE

FIG. 22. FRONT VIEWS OF HANDS OF A HUMAN FETUS, AND ADULT MAN, AND AN ADULT CHIMPANZEE

THE STRAIGHT LINES INDICATE THE TRANSVERSE AXIS OF THE THUMB, AS DETERMINED BY THE NAIL.

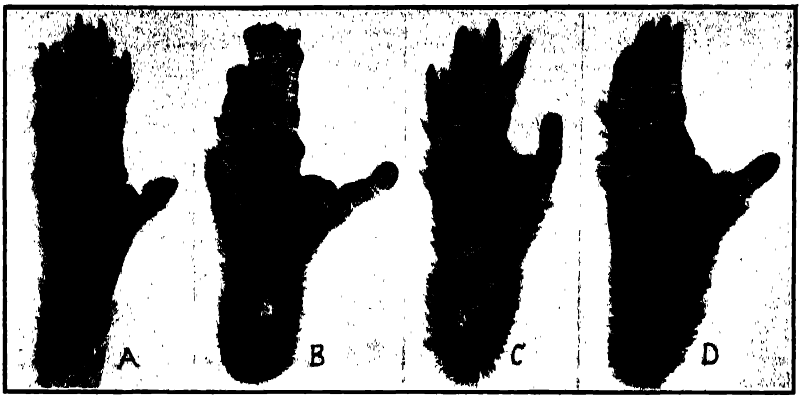


FIG. 23. FEET OF *A* = MARMOSET (230); *B* = NIGHT MONKEY (242); *C* = CAPUCHIN (249 *a*); *D* = SPIDER MONKEY (248 *a*)
ALL FROM CENTRAL AMERICA.

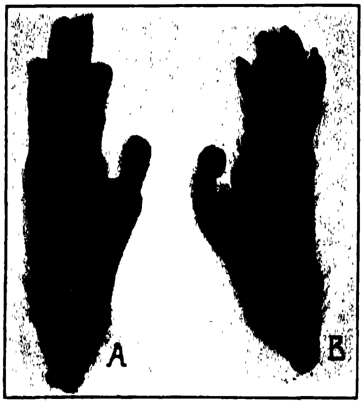


FIG. 24. FEET OF *A* = LANGUR (180); *B* = PROBOSCIS MONKEY (68).

other fingers (Fig. 22). The degree of opposability attained by the human thumb in adult life is less than that acquired by some adult chimpanzees, as shown by the example in Fig. 22. That adult man possesses the relatively longest thumb of all catarrhines represents a far smaller departure from the general condition than the opposite extreme, consisting in the complete loss of the thumb in the guereza. If, finally, the human hand appears broad alongside the long and slender hands of monkeys and most apes, its breadth seems very conservative in comparison

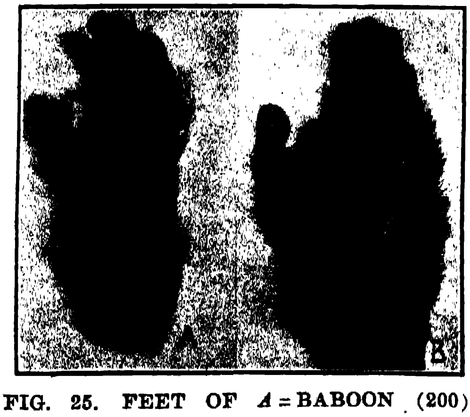


FIG. 25. FEET OF *A* = BABOON (200); *B* = SIAMANG (NO. 255980, NATIONAL MUSEUM).

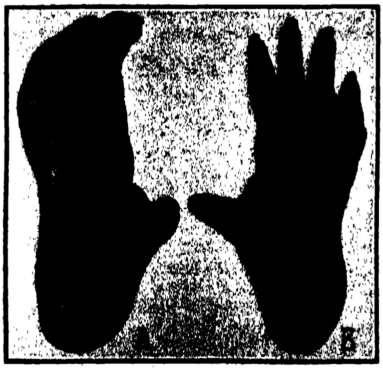


FIG. 26. FEET OF TWO ORANG-UTANS *A* = ADULT MALE (212); *B* = JUVENILE MALE. (37). PHOTOGRAPHED FROM PLASTER CASTS BY THE AUTHOR.

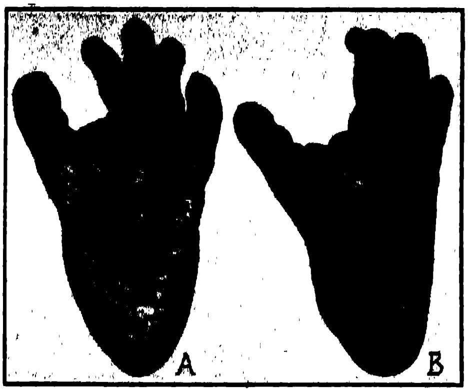


FIG. 27. FEET OF TWO CHIMPANZEES
A = JUVENILE MALE (163); *B* = JUVENILE MALE (162). PHOTOGRAPHED FROM PLASTER CASTS BY THE AUTHOR.

with the excessive broadening of the enormous hand of gorilla.

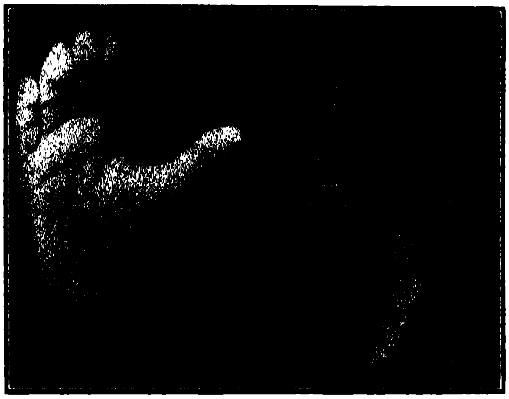


FIG. 29. FEET OF TWO GORILLA FETUSES
A = LOWLAND GORILLA, 89 MM SITTING HEIGHT (No. 7698, CARNEGIE MUSEUM); *B* = MOUNTAIN GORILLA, 205 MM SITTING HEIGHT (FROM A PHOTOGRAPH SENT BY PROF. I. BROMAN).

FOOT

The foot of primates is somewhat less uniform than the hand, though none of the five digits on the foot have become lost in any primate. In all New World monkeys the foot is long and slender, the great toe is short, abduced, and very little rotated, and the digits II to V are much lengthened (Fig. 23). The second toe is never as long as the third, which is generally the longest of all five toes. In most marmosets (Fig. 23 A), uakaris, sakis, and night monkeys, however, the fourth toe surpasses even the third in length. In the marmosets and tamarins the "great toe" appears almost rudimentary in comparison with this toe in the higher platyrrhines.

The foot of Old World monkeys (Fig. 24) is very similar to that of the

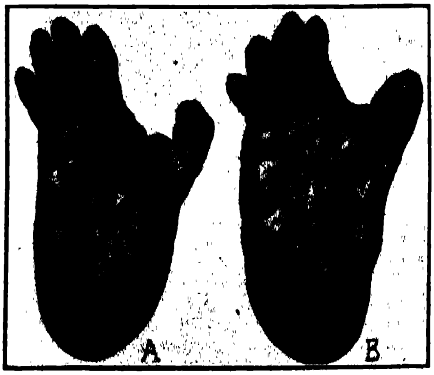


FIG. 28. FEET OF TWO GORILLAS
A = ADULT MALE LOWLAND GORILLA (CAST BY THE AUTHOR OF SPECIMEN LENT BY MUSEUM OF COMP. ZOOLOGY, HARVARD UNIV.); *B* = ADULT MALE MOUNTAIN GORILLA (CAST SENT BY AMER. MUSEUM OF NATURAL HISTORY).

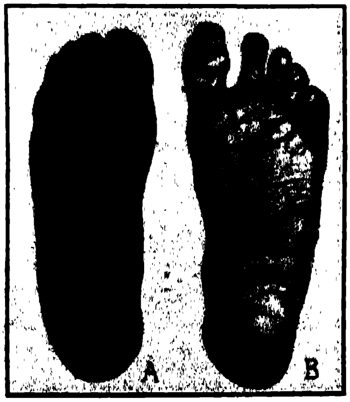


FIG. 30. FEET OF *A* = ADULT MALE NEGRO (P. A. L. 26); *B* = ADULT MALE AUSTRALIAN ABORIGINAL (P. A. L. 15) (CAST OF SPECIMEN SENT BY PROF. A. L. BURKITT).

FIG. 31. FOOT SKELETON
A = MOUNTAIN GORILLA; *B* = NEGRO.

higher American monkeys. As in the latter, the foot is long and slender, the great toe is proportionately short, and the second to fifth toes are greatly lengthened in all the arboreal forms, though fairly short in the terrestrial baboon (Fig. 25 A). In many of the catarrhine monkeys the second toe is as short as, or shorter than, even the fifth, and the fourth toe is often as long as, but very rarely longer than, the third (Fig. 24).

The foot of the gibbons and the siamang (Fig. 25 B) differs from that of the lower catarrhines chiefly in regard to the relative length of the first toe. This toe is of very considerable length in the siamang and proportionately still longer in most gibbons. In this group, for the first time, can the second toe equal or surpass the fourth in length. In all siamangs and a variety of gibbons the second and third toes are united by a cutaneous web, a condition which appears occasionally in man and is then inherited.[8]

Among all the many platyrrhine and catarrhine monkeys, the gibbons and the siamang the outer foot is more uniform than it is among the anthropoid apes and man. The Figs. 26 to 30 demonstrate best the remarkable adaptability to special function of the foot in the largest of the primates. The opposite extremes are represented by the most arboreal form, the orang-utan, and the most terrestrial, man. These extremes are connected by intermediate stages, existing in the feet of chimpanzee, lowland gorilla, and mountain gorilla. In the orang-utan the second, third, and fourth toes have become proportionately longer even than in the gibbons. The phalangeal bones within these digits are curved and perfectly adapted for grasping around the limbs of trees. The great toe of orang-utan has shifted farther back toward the ankle than in any other simian, and has degenerated at least as much as in the marmosets. In many orang-utans the great toe has lost its nail and one of the normally two phalanges. In the chimpanzee the great toe is well developed and in some specimens it can reach even to the end of the middle segment of the second toe (Fig. 27 A). The lateral toes are not nearly as long as in the orang-utan and the sole is relatively broader than in monkeys. In the lowland gorilla (Fig. 28 A) the foot has become even broader and the digits II to V are proportionately shorter than in chimpanzees. The sole extends forward to nearly the end of the basal segment of the third toe. In the mountain gorilla (Fig. 28 B) the sole reaches even farther, *i.e.*, almost to the base of the terminal phalanges, which is at least as far as in man. The free portion of the great toe of the lowland gorilla is still longer than in the mountain type, but in the latter the great toe projects farther forward than in the former on account of its greater *total* length. As shown by Fig. 29, these marked differences between the feet of the two gorilla species are already well defined in fetuses.

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[8] A. H. Schultz, "Zygodactyly and its Inheritance," *Jour. Heredity*, XIII, 1922. W. L. Straus, Jr., "The Nature and Inheritance of Webbed Toes in Man," *Jour. Morphol. and Physiol.*, XLI, 1926.

In all the anthropoid apes the middle toe is the longest and the second toe usually shorter than the fourth, but at times equally long or even longer. In man the second or even the first toe has become the longest of all, but only in the course of growth, since in young human fetuses the great toe is as yet short and much abduced and the middle toe is frequently seen to project beyond all others. The relative length of the free portion of the great toe in the Australian (Fig. 30 B) differs less from that character in the mountain gorilla (Fig. 28 B) than the latter differs in this respect from a chimpanzee (Fig. 27 B). The great toe of man does not branch from the most distal point of the sole, since its place of attachment has not yet reached entirely the base of the second digit. In all adult primates the outer great toe has been found to branch from the sole proximally to the base of the second toe. In orang-utan this point of branching lies closest to the ankle and in man closest to the second toe, the mountain gorilla differing in this respect more from the former than from the latter.

The peculiarity of the human foot is due principally to two evolutionary changes which followed the loss of the grasping function: (1) The nearly complete adduction of the great toe and (2) the unequaled shortening of the phalanges of the toes II to V. The adduction of the great toe is not yet present in the human fetus and the joint at the base of this toe is still curved and pointing toward the side in man, as in the apes with a movable great toe (see Fig. 31) and for further, details the paper quoted in footnote (6). The shortening of the lateral toes is best shown by quoting a few averages of the percentage relation between the length of the phalanges of the middle toe and the total foot length. In monkeys these phalanges form approximately 38 per cent. of the total length of the foot skeleton, in gibbons 41 per cent., in orang-utan 43 per cent., in chimpanzee 36 per cent., in gorilla not quite 33 per cent., but in adult man only 21 per cent. In the human fetus, however, this percentage is still 33. These toes of man, therefore, become proportionately much shorter during the development of the individual, just as they became reduced in the course of the evolution of the species. As shown by the example in Fig. 31, this evolutionary shortening has affected most of all the middle phalanges, which are completely lacking in some persons and fused with the terminal phalanges in many other human beings.

It is due to this shortening of the lateral toes that the great toe of man has acquired the distinction of being as long as, or longer than, all the other toes. That the second toe of man equals or surpasses the third in length is no greater a specialization than that other evolutionary trend by which the fourth toe has become longer than the middle one in a variety of the lower platyrrhines.

According to all anatomical and embryological comparisons the foot of man can be nothing else but a modification of a type of foot which has also given rise to the feet of modern anthropoid apes.

CONCLUSIONS.

Man's place within the mammalian order of primates can not be understood and properly evaluated without as close a study of all the monkeys and apes as of man himself. A comprehensive census of all the simian primates would result chiefly in a long list of the large variety of monkeys scattered over the tropical and subtropical zones. Appended to this list would be the names of a few higher primates. All the monkeys represent a multitude of different minor specializations with here and there some type attempting to rise above the others. They are all just "monkeys," have tails, a dense coat of hair, a slender trunk, narrow hands and feet, a very limited intellect, and many other quite primitive features. This, in spite of many detailed distinctions, comparatively uniform majority of primates contrasts sharply with the small minority: the gibbons, apes, and man. This second and outwardly heterogeneous group has been carried many evolutionary steps above the level attained by even the highest of the large first group. All the evidence from comparative anatomy and embryology points toward one common origin for this second class of simians. From this ancestral stock they must have soon spread along more or less diverging courses, even though they inherited many of those general tendencies which not only had started but also continued to lift them above the rest.

Of this select company the gibbons have undoubtedly progressed least and the siamang but little more. In many characters they have preserved evolutionary stages intermediate between certain little differentiated catarrhine monkeys and the anthropoid apes, particularly the orang-utan. Man and the three large apes share the distinction of representing the few most advanced experiments in all primate evolution. In some respects man has become more highly specialized than the apes, but in regard to many other features this relation is reversed.

These conclusions are supported and illustrated by the examples of evolutionary trends which have been discussed in this paper. A few of the clearest and most significant trends are briefly summarized in the accompanying tabulation.

It seems hardly necessary to state as a final conclusion that man is one of the few higher primates and resembles most closely the anthropoid apes, particularly the gorilla and chimpanzee, a resemblance which is in general greater than that existing between the large apes and the monkeys.

GENERAL TREND

Character	*from* most primitive condition among monkeys	*to* condition in large apes and man	Extreme in:
Body size	small	large	gorilla
Hair	very dense	relatively sparse	man
Tail	long	extremely reduced	gibbon
Spine	few sacral vertebrae many thoracolumbar vert.	many sacral vertebrae fewer thoracolumbar vert.	gorilla orang-utan
Trunk	slender	stout	gorilla
Chest	narrow	broad	gorilla
Upper limb	short	long	gibbon
Lower limb	short	long	man
Hand	slender	slender to very broad	gorilla
Thumb	very little opposable attached near 2nd finger	opposable shifted toward wrist	man and chimpanzee gibbon
Foot	slender	slender to broad	gorilla
Toes II to V	long	very long very short	orang-utan man

RHENIUM[1]

By Dr. WILLIAM F. MEGGERS
U. S. BUREAU OF STANDARDS

IT is a long step from the four elements, "earth, air, water and fire," of the ancient Greek philosophers to the 92 chemical elements now recognized as a group of elementary substances from which all bodies are made. Through many centuries the concept of elements has developed, gradually changing to correspond to newly discovered facts so that at the present time the word itself has acquired a new meaning. The chemical elements are now regarded as a series of atomic systems increasing in weight and complexity from hydrogen to uranium.

A small number of chemical elements were known in prehistoric times; the list includes silver, gold, carbon, copper, iron, mercury, lead, sulphur and tin. No doubt their discovery was purely accidental. The middle-age alchemists probably deserve some credit for discovering arsenic, bismuth, phosphorus, antimony and zinc, but the remainder of the known chemical elements have been discovered since the beginning of the eighteenth century, when chemistry became a true science. The complete story of these discoveries is as interesting as any adventure or romance ever narrated. Just now one of the final chapters of this story has been written; it deals with the discovery and description of rhenium.

The atomic conception of matter is also very ancient. Some of the Greek philosophers of the third and fourth centuries B. C. taught "that all substances are formed of indivisible particles or atoms which are eternal and unchangeable, that the atoms are separated from one another by void, and that these atoms, by their combinations, form the matter we are conscious of."

The prestige of Aristotle who believed matter to be infinitely divisible and continuous is responsible for delaying any development of the idea until the seventeenth century when the work of Boyle, Newton, and others laid the foundation of analytical chemistry. During the next two centuries, chemical methods and technique were perfected at a remarkable rate, important laws were discovered and knowledge was classified so that it became possible to characterize and distinguish different chemical elements with great refinement. Thus by the end of the nineteenth century, 85 different elements had been identified and described.

In the second half of this period a new method of detecting and identifying chemical elements was announced by Bunsen and Kirchhoff. It is based on the observation that each chemical element, when rendered luminous in the gaseous state and viewed with a spectroscope, exhibits colored images or lines which are uniquely characteristic of the element. With the aid of spectral analysis several new elements (rubidium, caesium, gallium, indium, thallium, and some of the rare gases) were discovered.

Another factor which has played an important rôle in the discovery of new chemical elements is the so-called periodic classification which was stated in essentially its present form by Mendeléev in 1871. Although earlier attempts had been made to correlate chemical properties of elements with atomic weights, Mendeléev was the first to recognize combining power (valency) as the outstanding periodic property of the elements. On this periodic classification, in which the elements are now arranged in eight vertical groups having valency from 1 to 8, is

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[1] Publication approved by the director of the Bureau of Standards of the U. S. Department of Commerce.

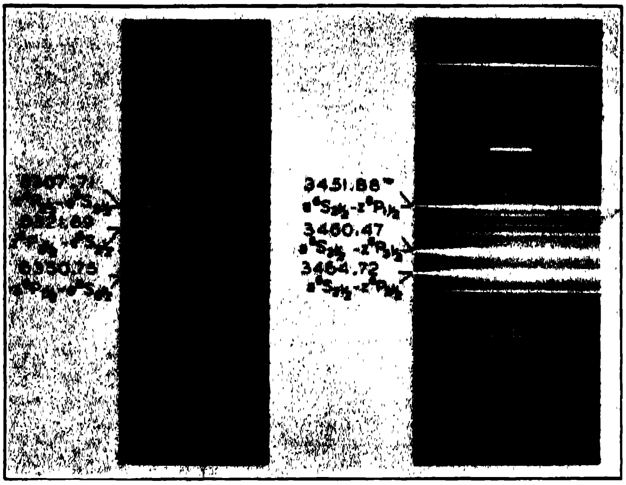

FIG. 1. TWO TRIPLETS IN THE ARC SPECTRUM OF RHENIUM, ONE IN THE ULTRA-VIOLET (3451.88, 3460.47, 3464.72A) AND THE OTHER IN THE RED (6307.71, 6321.89, 6350.75A). THEY ARE ENLARGED TO THE SAME FREQUENCY SCALE TO SHOW THAT ONE ATOMIC ENERGY STATE (z^6P) IS COMMON TO BOTH TRIPLETS. TRANSITIONS FROM THIS THREEFOLD EXCITED STATE TO THE NORMAL STATE OF THE ATOM (a^6S) GIVE RISE TO THE FIRST TRIPLET, WHILE TRANSITIONS TO A STILL HIGHER EXCITED STATE (e^6S) ACCOUNT FOR THE SECOND TRIPLET. THESE GROUPS OF LINES GAVE THE CLUE TO THE STRUCTURE OF THE SPECTRUM AND OF THE ATOM. THE LINE AT 3460.47A IS THE MOST SENSITIVE ONE FOR DETECTING RE, IT WILL DISCLOSE A SINGLE RE ATOM IN THE PRESENCE OF 30,000,000 OTHER ATOMS.

based practically the entire modern system of chemical knowledge and also the scientific theories of the electronic structure of atoms. Certain blank spaces in the periodic system as constructed by Mendeléev corresponded to unknown chemical elements, thus giving the first clue to the number and nature of different elements which were still undiscovered.

Only at one place in the periodic system as originally proposed was there an uncertainty as to the number of elements in a period. This was in an exceptionally long period containing a group of elements known as the "rare earths," all of which have the same chemical valency. Laborious methods of separation disclosed more and more elements of this type without suggesting any definite limit to their number.[2] Such a limit was finally imposed in 1913 by Moseley's discovery that the characteristic Röntgen spectra change from element to element in a continuously progressive manner. Following this discovery each chemical element was assigned an atomic number, beginning with hydrogen 1 and ending with uranium 92, and it was seen that only six (atomic numbers 43, 61, 72, 75, 85 and 87) remained unknown.

The identification of chemical elements by means of their Röntgen spectra furnished a new method of attack on the unknown ones—hafnium 72 being discovered in this way in 1923, and the only remaining unknown rare earth, 61, detected in the same way a few years later. This left only four possible chemical elements to search for and two of these, 85 and 87, are probably radioactive, extremely unstable, and too scarce to be detected by any of the recognized methods now available. Thus, finally, only two theoretical atomic numbers, 43 and

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[2] The total number of rare earths is now known to be 14; they are cerium, praseodymium, neodymium, illinium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutecium.

75, offered any promise of adding further members to the family of known chemical elements. Indeed, these two, among others, were predicted by Mendeléev in 1869; they were referred to as eka-manganese and dvi-manganese because they represented blank spaces under manganese in the periodic classification of the elements. Many attempts, both chemical and spectroscopic, had been made to detect these homologues of manganese, but none were successful until 1925, when two German chemists, Walter Noddack and Ida Tacke, announced[8] that both 43 and 75 had been chemically concentrated from platinum ores and rare-earth minerals, and had been identified by their Röntgen spectra. The newly detected elements were named masurium (Ma, 43) and rhenium (Re, 75) after the east and west boundaries of Germany.

The discoverers of 43 and 75 proceeded on the assumption that these elements had not been discovered heretofore because of their extreme scarcity, estimating that the earth's crust should contain about 1 part in a million million (10^{-12}) of 75 and 1 part in 10 million million (10^{-13}) of 43. Guided by the predicted chemical properties, Noddack and Tacke carefully carried out planned chemical processes with selected ores and minerals until a sufficient concentration of the new elements revealed their presence by the appearance of accurately predicted lines in the Röntgen spectra. The discovery was announced when a minute quantity of material estimated to contain about 0.5 per cent. masurium and 5 per cent. rhenium furnished the following table of Röntgen spectra, in which wave-lengths are expressed in Angstrom units (10^{-10}m):

Apparently little progress has been made in further concentration and purification of masurium, but the supply of rhenium has increased in an astonishing manner. Only 2 mg of rhenium had been purified in 1927, about 120 mg were

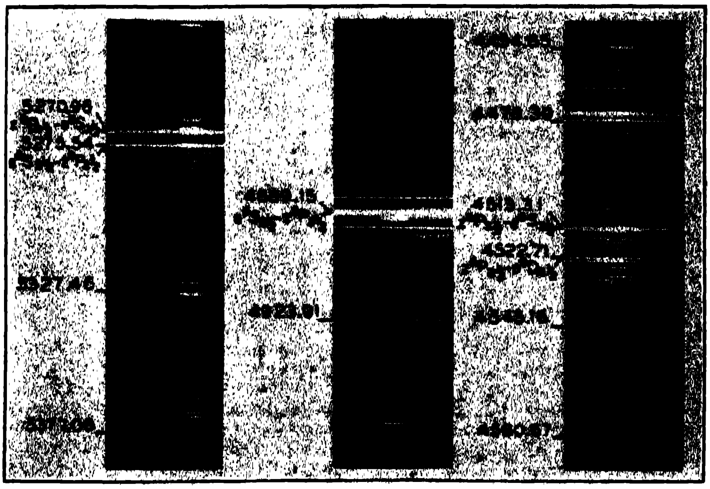

FIG. 2. PORTIONS OF THE ARC SPECTRUM OF RHENIUM IN THE BLUE AND GREEN

THE LINES AT 5275.54 AND 4889.15A ARE THE MOST EASILY EXCITED LINES OF RHENIUM. THE SYMBOLS, $a^6S_{2\frac{1}{2}} - z^6P_{3\frac{1}{2}}$, REPRESENT THE TYPE OF ATOMIC ENERGY CHANGE WHICH PRODUCES THE PARTICULAR LINE. THE ATOMIC ENERGY STATES OF RHENIUM ARE, IN GENERAL, POLYFOLD AND THE MAXIMUM MULTIPLICITY CAN BE EITHER 4, 6 OR 8. THE SHORT LINES SUPERPOSED ON THE RE SPECTRA IN FIGS. 1 AND 2 BELONG TO THE IRON ARC SPECTRUM, WHICH IS USED AS A STANDARD SCALE FOR MEASURING THE WAVE LENGTHS OF LINES IN OTHER SPECTRA.

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[8] W. Noddack and I. Tacke, *Naturwissenschaften* 13, p. 567; 1925.

	Masurium 43			Rhenium 75				
Line symbol	K_{α_1}	K_{α_2}	K_{β_1}	L_{α_1}	L_{α_2}	L_{β_1}	L_{β_2}	L_{β_3}
Measured Wave-length	0.672	.675	.601	1.4299	1.4407	1.235	1.2048	1.216
Calculated Wave-length	0.6734	.6779	.6000	1.4306	1.4406	1.2355	1.2041	1.2169

prepared in 1928, the production of an entire gram was described in 1929, while the possibility of an annual production of 120 kg as a by-product from a single chemical plant was announced in 1930. The price of rhenium was about $10,000 per gram in 1928; in 1929 it fell to $50, and in 1930 to $3 per gram.

Along with the increasing availability of rhenium has come an extensive accumulation of facts as to its chemical and physical properties.[4] A large number of chemical compounds of rhenium have been prepared and studied. For example, it has been found that rhenium prefers a valency of 7 or 6; its higher oxides are more stable than those of manganese. Burning rhenium in a stream of oxygen gas produces a series of oxides as follows: white oxide (Re_2O_8), yellow oxide (Re_3O_7), red oxide (ReO_3), blue oxide (Re_3O_8), and black oxide (ReO_2). The last, when heated to 800° C. in hydrogen, reduces to rhenium metal. Rhenium metal can also be prepared by reduction of the sulphide or of potassium or ammonium perrhenate. Especially simple and efficient is the reduction of potassium perrhenate ($KReO_4$). Only minute quantities of rhenium are obtainable as a cathode deposit in electrolysis. Tests of the stability of the metal in the presence of oxidizing gases at high temperatures show that rhenium is considerably more noble than tungsten. It dissolves readily in nitric acid (HNO_3), slowly in sulphuric acid (H_2SO_4), and practically not at all in hydrofluoric (HF) and hydrochloric (HCl) acids. The atomic weight of rhenium has been determined to be 186.31. Its atoms have been found[5] to consist of 2 isotopes with mass numbers 185 and 187, as was expected from the general rule that complex elements of odd atomic number (above 9) consist of 2 odd mass numbers 2 units apart; but this is the first element analyzed in which the heavier isotope is the more abundant, the ratio being estimated as 1.62 to 1. These are only a few of the new facts which rhenium has brought to chemistry.

We shall now review very briefly what has been learned about the physical properties of this new element: Its melting point has been determined to be 3440° ± 60° on the absolute scale of temperature. Although this temperature is high it is about 250° lower than the melting point of tungsten. The density of rhenium metal is about 21 times that of water, its crystal form is hexagonal and its atomic radius is 1.382A. The metal possesses some ductility and can be hot forged and rolled. The specific electrical resistance of rhenium at ordinary temperature is 0.21×10^{-4} ohm cm ± 15 per cent., four times that of tungsten. The temperature expansion coefficient is found to be 2.7 times greater in the direction of the crystal axis than at right angles to it, *viz.,* 12.45×10^{-6} and 4.67×10^{-6}. The electron emission of rhenium has been measured in the temperature range 1900° to 2700°K; it emits only $\frac{1}{3}$ to $\frac{1}{4}$ as strongly as tungsten, or with the same intensity as tungsten at a temperature 150 to 200° lower.

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[4] I. and W. Noddack, *Zeit. Angew. Chem.*, 125, p. 264, 1927; *Zeit. Elektrochemie*, 34, p. 627, 1928; *Naturwissenschaften*, 17, p. 93, 1929; C. Agte, H. Alterthum, K. Becker, G. Heyne, and K. Moers, *Zeit. Anorg. Allgem. Chemie*, 196, p. 129, 1931. This is by no means a complete list of publications on the properties of rhenium, but the papers listed here will be found to contain references to other publications.

[5] F. W. Aston, *Nature*, 127, p. 591, 1931.

Perhaps the most important and interesting property of any atom is its power to emit or absorb radiation; this importance arising from the fact that such radiation identifies an element uniquely, and interesting because it reveals the electronic structure of the atom. Of course, everybody knows that the quondam "indivisible" atom has been subdivided into protons and electrons, the unit positive and negative electrical particles (or waves), which are now regarded as the unresolvable ultimates. According to a theory proposed by Bohr in 1912, the atoms resemble the solar system in that a nucleus (consisting mainly of protons) corresponding to the sun is surrounded by electrons in definite orbits like the planets. From this concept of an atom the "quantum theory of spectroscopy" has been developed to account for the observed monochromatic radiations emitted by atomic systems. On the basis of this theory a spectral line corresponds to a definite change in energy of an atomic system; indeed the frequency of the radiation multiplied by a universal constant (h) is exactly equal to the energy change. The changes of atomic energy were assumed to represent changes in the orbits of the planetary electrons, and, guided mainly by a few known facts of optical spectra, Bohr was able to outline a process of atom building which specified the number of electrons and described the orbit of each that entered into the structure of an atom. In this way the periodic classification of the chemical elements was arrived at from spectroscopic data, and the road to further knowledge about atoms was paved. During the past five or six years different types of atomic energy changes (usually called spectral terms) have been recognized; these have been correlated with electron orbits and configurations so that all spectroscopic phenomena are now assigned to definite atomic systems and activity. This development has made it possible to infer the structure of an atom from the analysis of its spectrum.

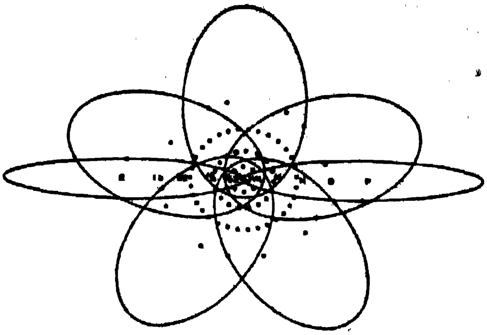

FIG. 8. THE RHENIUM ATOM ACCORDING TO BOHR'S THEORY

AND RECENT DEVELOPMENTS IN THE CORRELATION OF SPECTRAL STRUCTURE WITH ELECTRON CONFIGURATIONS IN RADIATING ATOMS. THE NUCLEUS IS A TINY SPECK IN THE CENTER OF THE FIGURE. THIS IS SURROUNDED BY 75 ELECTRONS GROUPED IN SUCCESSIVE SHELLS AS SHOWN, THE OUTERMOST GROUP CONSISTING OF 7 VALENCE ELECTRONS FOR WHICH THE ORBITS ARE DRAWN. RÖNTGEN SPECTRA ORIGINATE WITH ATOMIC ENERGY CHANGES OCCURRING WHEN ELECTRONS IN THE INNER SHELLS K, L, M, ETC., ARE DISPLACED FROM THEIR NORMAL POSITION, WHILE THE OPTICAL SPECTRUM IS PRODUCED BY ORBITAL CHANGES OF THE OUTER ELECTRONS. THE ACTUAL DIAMETER OF THE RE ATOM IS ABOUT 0.000000001 INCH.

The first spectral data for rhenium were the Röntgen lines already quoted; they constituted the first proof of the existence and capture of this new element. Investigations of the Röntgen spectra of rhenium were soon extended and in 1928 detailed descriptions had been published.[8] In the same year the discoverers announced that the arc and spark spectra of rhenium were qualitatively known and that several hundred lines were known certainly to belong to it. No further information was given except that the ultimate lines of the optical spectrum serve to detect rhenium in concentrations down to 1 part in 10 millions. The last statement suggests that the optical spectrum is of considerable practical importance in the search for rhenium-containing ores or minerals because the ultimate line of the optical spectrum is probably the most sensitive test for rhenium that can be found. The Noddacks assert that the optical spectrum is sensitive to 10^{-7} while the Röntgen spectrum can not detect rhenium in concentrations less than 2×10^{-4}. Examination of 1600 minerals from all parts of the world has revealed rhenium in 100 of them but never more than 0.001 per cent. or 10^{-5}. This explains why all attempts to detect rhenium in minerals by means of Röntgen spectra failed until Noddack and Tacke conceived the plan of first enriching 1,000 fold by chemical processes the concentration which might be expected in certain minerals. It also accounts for the entire absence of rhenium lines from tables of the characteristic spectra of other chemical elements, a case quite different from hafnium which was first identified by recognition of its predicted Röntgen spectrum in ordinary zirconium minerals, and was later found to have been represented for many years by hundreds of lines in the emission spectrum tables ascribed to zirconium. The natural concentration of hafnium in zirconium ores averages several per cent., while no ores contain more than 0.001 per cent. of rhenium, so that the difference in behavior is due to great disparity in concentration rather than to a difference in sensitivity of the ultimate spectrum lines.

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[8] H. Beuthe, *Zeit. Physik.*, 50, p. 762, 1928.

Spectral lines of hafnium were positively identified with faint lines in the solar spectrum but a similar comparison of rhenium with Fraunhofer lines disclosed no coincidences. This does not disprove the presence of rhenium in the sun, it only indicates that the concentration of rhenium in the reversing layer of the sun's atmosphere is less than 10^{-7}. The earth's crust consists of about 10^{-5} hafnium and, according to the latest estimates, of about 10^{-9} rhenium. If we assume the same ratio to exist in the sun the detection of hafnium lines in the solar spectrum and the failure to find rhenium lines are both fully explained.

A complete and accurate description of the optical spectrum of rhenium, and the analysis of its structure, are the latest contributions[7] to our knowledge of the properties of this new atom. The light of an electric arc in which rhenium is vaporized has been photographed with the largest spectrographs at the Bureau of Standards; about 3,000 new lines ranging in wave length from 2,100 A in the ultra-violet to 8,800 A in the infra-red have thus been added to the data of spectroscopy. The relative intensities of these have been estimated on a scale ranging from 1 to 2,000 and practically all the stronger lines have been accounted for as transitions between atomic energy states, many of which have been identified with electron configurations in the atom. Thus it has been established that the normal state of the rhenium atom is described by a spectral term associated with 7 valence electrons, and certain excited states are definitely identified with orbital changes of one or more of these outer electrons. Series-forming terms have been recognized which permit a calculation of the ionization potential of the rhenium atom. This is a measure of the stability of the group of valence electrons. It is expressed as the potential difference through which a free electron must fall to acquire sufficient energy to remove one of the valence electrons upon collision, and for rhenium atoms it is found to be 7.85 volts. Some of the more prominent and significant lines of the rhenium spectrum are shown in Figs. 1 and 2, and as a crowning achievement a picture of the rhenium atom as deduced from its optical spectrum is given in Fig. 3.

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[7] W. F. Meggers, *B. S. Journ. Res.*, 6, p. 1027, 1931 (R. P. 322).

THE MATHEMATICAL WEAKNESS OF THE EARLY CIVILIZATIONS

By Professor G. A. MILLER
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DURING the last few years the mathematical public has enjoyed at various times the invigorating experience of changing its mind as regards the mathematical attainments of the ancient Babylonians and the ancient Egyptians. A number of new discoveries relating thereto have been announced in a historical publication inaugurated in 1929 under the title "Quellen und Studien zur Geschichte der Mathematik" which appears in two series entitled "Quellen" and "Studien" respectively. The first volume of the former series (1930) is devoted to a translation into German of the noted Moscow Mathematical Papyrus by Professor W. W. Struve. It may be of interest to note here that on page 181 thereof, Professor Struve makes the following comment which is in disaccord with the view commonly expressed: "In no case can the Babylonian mathematics be regarded as on a higher level than the Egyptian, even if we should soon become acquainted with more formulas from the cuneiform inscriptions than from the hieratic papyri."

This relatively favorable view as regards the ancient Egyptian mathematics was based to some extent on the widely different character of the sources of our present knowledge relating to the mathematics of the ancient Babylonians and the ancient Egyptians. Professor Struve pointed out that in the case of the former our knowledge is based on what appears in large collections which may have been royal or temple libraries, and, therefore, on what was probably the best of the periods concerned, while in the case of the latter it is based on scattered discoveries which may not represent the most advanced attainments of their times. Judging from the material actually available at the present time there seems to be no question as regards the relative superiority of the Babylonian mathematics, as was pointed out by Professor O. Neugebauer on page 325, volume 1 (1930), of the "Studien" noted above.

One of the most instructive studies in the history of mathematics relates to the values used by various peoples for the ratio of the circumference of a circle to its diameter. It is well known that in this respect the ancient Egyptians are supposed to have excelled all other pre-Grecian nations since they assumed that the area of a circle is equal to that of a square whose side is eight ninths of the diameter of the circle. This implies that the ratio in question is the fourth power of four thirds and some mathematical historians have assumed that the ancient Egyptians realized this implication. A much cruder value for this ratio is the number 3 which appears in the literature of various ancient countries, including Babylonia, and is also found in our Bible. It would not have required a very carefully planned experiment to exhibit the inaccuracy of this and every other assumed value for this ratio on the part of the pre-Grecian mathematicians, but as far as is now known such an experiment was never made before the times of the ancient Greeks notwithstanding its simplicity.

The fact that very crude approximations for the value of the ratio of the circumference of a circle to its diameter were commonly employed even in medieval times, and were often regarded as accurate, seems to imply that credulity rather than experimentation has been the prevailing trait of the human race, especially in the early civilizations. By measuring the circumferences and the diameters of the wheels of their chariots with care they could readily have found that the commonly assumed values of this ratio are inexact and it is somewhat surprising that those who constructed these chariots did not point out the inaccuracy in such prevailing views relating thereto. The recent discoveries relating to the mathematical attainments of the ancient Babylonians and the ancient Egyptians make it more desirable to emphasize the noted shortcomings since otherwise these discoveries would be apt to convey an incorrect impression of the true situations.

A true picture of the mathematical attainments of ancient civilizations implies an emphasis on the evidences of weakness as well as on the evidences of strength. In the histories of mathematics the attention is too frequently confined to the latter. For instance, in his work noted above Professor Struve stresses the relative accuracy of the supposed value used by the ancient Egyptians for the ratio of the circumference of a circle to its diameter as compared with that used by the ancient Babylonians. It is, however, more important to note that there is no evidence tending to show that even a single pre-Grecian mathematician discovered a method for finding the value of this ratio to any desired degree of accuracy. In this respect all the pre-Grecian mathematics is on a level and exhibits the same lack of coordination of theoretical and applied mathematics. In fact, the various assumptions in regard to this ratio furnish one of the clearest illustrations of a tendency towards pure mathematics in ancient times. It was much easier to make assumptions or to accept the statements of others relating thereto than to test their accuracy by actual measurements.

One of the most striking recent discoveries relating to the ancient Egyptian mathematics is the very early use of the theorem that the area of a hemisphere is equal to that of two great circles of the same sphere. It is, however, somewhat misleading to say that the ancient Egyptians had a correct rule for finding the area of a hemisphere since there is no evidence tending to prove that they could find the area of a circle to any desired degree of accuracy. In view of the crudity of their rule relating to the latter as judged from the modern point of view it does not seem justifiable to assume that they were able to prove the remarkably elegant theorem that the area of a sphere is equal to that of four great circles of the same sphere. At any rate, it is very important to bear in mind that, in the pre-Grecian mathematics which has become known to us, proofs are almost completely lacking and that this is an outstanding evidence of weakness in their mathematical developments as compared with those of modern times.

Mathematics has become a republic by means of its proofs since these have enabled the individual to build his own storehouse of mathematical knowledge. Real proofs in mathematics are, however, impossible without postulates. Up to the present time we have no evidence tending to prove that any explicit use of mathematical postulates was made before the period of Greek mathematical activity or that any pre-Grecian mathematician realized the need of such postulates. While the ancient Babylonians and the ancient Egyptians reached an advanced stage of civilization along certain lines, their extant mathematics is woefully lacking as regards some of the elements which are most fundamental. They did, however, deal with a number of abstract mathematical notions including that of positive rational numbers. In fact, the ancient Babylonians used also sexagesimal fractions and paid much attention to converting common fractions into the form of sexagesimal fractions as has been proved recently by Professor O. Neugebauer in the "Studien" noted above.

According to these "Studien" we now know at least 19 Babylonian problems which give rise to quadratic equations and with respect to ten of these the details of the solutions are given. In some cases the method used corresponds to the modern method of completing the square and differs only from our modern procedure by omitting the double sign when the square root is extracted. All the earlier accounts, relating to the historical development of the quadratic equation have become antiquated during the last three years as a result of these discoveries relating to the mathematical attainments of the Babylonians during a period of at least 1,500 years, beginning about 2000 B. C. It is especially interesting to observe that this period overlaps that of the early Greek mathematical activity and hence the said discoveries establish a continuity in algebraic developments which had not been known to exist hitherto.

A remarkable element of weakness common to all the mathematics preceding the Christian era and extending several centuries beyond this period is the lack of the use of negative numbers. The nature of these numbers is so painfully and powerfully illustrated by debts as well as by distance in an opposite direction from those represented by the positive numbers that one can see that their usefulness could have been observed comparatively early in the development of abstract mathematics. It is therefore noteworthy that even the ancient Greek mathematicians, to whom we owe so many fundamental theorems of elementary mathematics, failed to extend the number concept so as to include the negative numbers and that this extension can not be regarded as really completed until about the beginning of the nineteenth century. Even such noted mathematicians as H. Cardan (1501–1576) and R. Descartes (1596–1650) sometimes reasoned very erroneously in regard to these numbers since the former tried to prove that $-a \times -b$ could not be equal to $+ab$ and the latter thought that negative numbers increased with the increase of their absolute values.

Elementary mathematics is a kind of intellectual currency which people commonly employ, like monetary currency, at its stamped values without much thought as regards the underlying structure. It is true that in mathematics we now aim to explain the fundamental principles, but teachers of this subject usually recognize at every examination of their classes that their efforts have been only partially successful. Hence much of the mathematics which is being used at the present time is imperfectly understood by many of those who are using it and the comparatively large amount of mathematics that is being used at the present time is largely due to the complexity of our civilization and not to an intrinsic interest in mathematical thinking. The fact that much less mathematics was employed in the ancient civilizations, therefore, does not reflect so much a lack of intellectual interest in this subject as a less urgent need of the type of intellectual currency represented by mathematics. In dividing by a fraction many persons invert the denominator and multiply because they were taught a rule to this effect and not because they comprehend the reason for this rule, which does not seem to have been explicitly formulated until several centuries after the beginning of the Christian era.

Our modern idea of mathematics is that it is mainly concerned with the formulations and proofs of general theorems. Both of these fundamental notions are almost completely lacking in the pre-Grecian mathematics. For instance, in the addition of common fractions it is now customary to reduce these fractions to their lowest common denominator and then to add the numerators thereof, but this rule has not yet been found in an explicit form even in the rich mathematical literature of the ancient Greeks. It is well known that the Rhind Mathematical Papyrus of the ancient Egyptians is largely devoted to operations with special common fractions but when such fractions are added they are sometimes considered with respect to a number which is not divisible by the denominators of all the fractions involved in the operation. It would obviously be unfair to regard the mathematics of the ancients as inferior to our own just because their methods differ from those now commonly employed, but the stating and proving of general theorems is not affected thereby and hence we have here definite evidence of weakness of the mathematics of the ancients as compared with that of modern times.

This weakness is only slightly affected by the recent discovery of the facts that the ancient Babylonians used the so-called Pythagorean theorem and that the ancient Egyptians used a rule for finding the volume of the frustum of a square pyramid which is equivalent to our modern formula relating thereto. The laboratory of the mathematician is his brain and its development depends on its use and not on an expensive physical equipment. It is therefore not surprising to find even in ancient times isolated instances of relatively advanced mathematical developments. In a primitive state of civilization such developments naturally attracted little attention. Even at the present time the mathematician reaches directly only a small number of interested persons and the new results of his work are usually preserved as a consequence of a very widely organized effort to disseminate useful knowledge and to simplify the determination of what is actually new. The history of the development of mathematics constitutes one of the most reliable and most suggestive aids to the study of the intellectual development of the human race.

Mathematics is a concomitant of civilization and the concept of number may antedate the beginning of the development of a language. Even some of the lower animals have exhibited a kind of number concept and primitive people are sometimes able to count far beyond their number words. Hence the reader may be surprised when he meets a statement like the following: "Not until modern times was unity considered a number," D. E. Smith, "History of Mathematics," volume 2, page 26, 1925. In the commonly accepted sense of the term unity was clearly regarded as a number by the ancient Babylonians as well as by the ancient Egyptians. It is, however, obviously possible to give a definition for the term number so as to exclude unity from the concepts involved therein and this was sometimes done by the ancient Greeks and by some later writers but as far as we know now it was not done by any earlier people. In answering the question "how many?" the number one, or unity, was naturally regarded as a number just as much as two, three, etc., were regarded as numbers, and this conception of number is very old. The unique properties of unity, such as the fact that every natural number after the first can be obtained by adding unity to the preceding and that a number is not changed when it is multiplied by unity probably did not impress the people forcibly before they attained a somewhat advanced state of intellectual development.

Since mathematics is mainly a mental science a large part of the mathematical developments are lost to this world with the deaths of the individuals concerned. Comparatively few have left a record of some of their mathematical work and in modern times such records are almost entirely confined to developments or results which are supposed to excel those left by predecessors. Hence our modern mathematics is from the nature of its development superior to that of earlier times and the relative mathematical weakness of the early civilizations is constantly becoming more pronounced. In view of the close interrelations between the various parts of mathematics, the comparative merits of ancient and modern work can perhaps be more readily seen here than in some of the other sciences. At any rate, the evolution of mathematics is definitely established notwithstanding long periods of halting and even of slight retrogressions. Our modern period of development seems to be one of unprecedented rapidity and to point to unlimited room for new advances. This applies especially to written work. Whether our progress in mental arithmetic is equally marked is difficult to determine. As far back as about 1300 B. C. the ancient Egyptians seem to have emphasized mental arithmetic as results from the following admonition: "When you calculate mentally do not allow a word to be heard."

WATER PURIFICATION AND SEWAGE DISPOSAL ON THE GREAT LAKES

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THE Great Lakes of North America, located on the border line between the United States and Canada, are the largest connected bodies of fresh water in the world. They have a combined water surface of 95,160 square miles, and their land drainage basins cover an area of 202,920 square miles. Over 64 per cent. of the water surface of these lakes lies within the boundaries of the United States.

The following table gives some interesting data for each of the lakes.

Name of lake	Greatest Length in miles	Greatest width in miles	Maximum depth in feet	Altitude above sea-level in feet
Superior	350	160	1,180	601.6
Michigan	307	118	870	579.6
Huron	206	101	750	579.6
Erie	241	57	210	570.8
Ontario	193	53	738	244.5

The outlet for these lakes is through the St. Lawrence River. Their maximum discharge, measured opposite Ogdensburg, N. Y., has been estimated as 320,000 sec. ft.; their minimum as 191,000 sec. ft.; and their mean as 210,000 sec. ft. Lake Superior, the largest single body of fresh water in the world, receives the flow from 200 rivers. The other lakes have many small streams entering them, none of which is very large.

Through the connecting straits, rivers, canals and the St. Lawrence River, a continuous waterway is provided for a distance of over 2,200 miles, as measured from Duluth to the Atlantic Ocean. The large population in the territory surrounding the Great Lakes, some of it being centered in our largest cities, the rich natural resources available for industrial purposes within adjacent land areas and the existing power and industrial developments at Niagara Falls, account for the enormous amount of waterborne traffic on these lakes. In 1926, 137,000,000 tons of raw and manufactured materials, valued at more than two billion dollars, were carried in lake vessels. In spite of the fact that navigation of the lakes is confined to approximately seven or eight months of the year, due to shore ice at lake ports and to dangerous storm conditions during the winter months, their tremendous economic value to the United States and Canada for water transportation purposes may be realized.

The water in the Great Lakes is usually of excellent quality for public water supplies when unpolluted by sewage. It is remarkably uniform in the kind and quantity of its chemical constituents. They are moderately hard waters and do not need to be softened unless a very soft water is required for industrial purposes. They are usually free from large amounts of suspended matter, except following storms which may stir up for short periods matter deposited on the bottom. On account of their usual clarity, they are frequently infested with microscopic organisms during the warmer months of the year. These organisms require sunlight for their propagation and are a frequent source of trouble in the operation of water purification plants. From the sanitary standpoint, the natural waters of these lakes are of great purity, but, as will be shown later, the problem of securing this water for public supplies is complicated by several factors, some of which are difficult, if not impossible, to overcome.

Intakes for public water supplies on the Great Lakes are either of the submerged type or are provided with a superstructure which projects above the surface of the lake. The intake cribs are connected to the shore by either pipe lines laid in a trench on the bottom of the lake, or by means of a tunnel under the bottom of the lake. The distance from shore at which intakes are placed varies greatly. It is desirable to place intakes in not less than 20 feet of water, if possible, and preferably in 35 to 40 feet. The slope of the bottom naturally fixes the location of the crib, if these depths of water above the intake are to be obtained. Consequently, intakes are found located anywhere from 1,000 feet to six miles from shore. Where compressed air is required to construct intakes and tunnels, it is probably not practicable to work in depths of water greater than 100 feet. Shallow shore waters may become filled with stranded ice floes during the winter months; a sandy or silted bottom may cause serious difficulties by clogging intakes, intake pipes and tunnels; and anchor ice may block the ports of cribs, if they are placed in too shallow water. All these conditions have a bearing on the quality of the water which may be obtained from the lakes, and obviously necessitate the conclusion, that, although the great body of the water in these lakes may be of a high degree of purity, only the waters within a few miles of the shore are really available for public water supplies.

While the natural impurities in the lake waters are relatively small in amount, the need for their removal is now generally recognized, especially as the standards for potable waters have advanced during the past two decades. The necessity for drinking water supplies of exceptional purity, as regards their bacterial content, is of even greater importance to the water consumer, since the removal of such pollution is insurance against water-borne diseases. This phase of the problem involves the nature and extent of the pollution of the available waters of the Great Lakes by sewage and trade wastes.

With the exception of the city of Chicago, which diverts its sewage through a canal into the Des Plaines River, which empties into the Illinois River, and the latter into the Mississippi River, all the sewage from the watershed of the Great Lakes eventually finds the way into them. While treatment and natural dilution may diminish the amount and danger from the impurities in these wastes, the fact remains that there is being discharged daily immense volumes of polluting matter into lake waters. Since from this same source is drawn the major part of the public water supplies for a large population on their shores, the danger of infection from water-borne diseases and the imperative need for the purification of water supplies are self-evident.

There have been several important investigations of the extent to which lake waters have been contaminated by sewage during the past twenty-five years. Probably the investigation which covered the greatest area was conducted by a joint commission provided by treaty between Great Britain and the United States, wherein the United States and the Dominion of Canada undertook to answer the question. "To what extent and by what causes and in what localities have the boundary waters between the United States and Canada been polluted so as to be injurious to public health and unfit for domestic or other uses." The second portion of the reference dealt with remedial measures. It will be noted that this investigation related only to "boundary waters between the United States and Canada."

The work was carried on during the years 1913 and 1914, and covered, so far as the Great Lakes are concerned, Lake Superior opposite Port Arthur, the St. Mary's River, the St. Clair River between Lake Huron and Lake St. Clair, Lake St. Clair, the Detroit River between Lake St. Clair and Lake Erie, the western end of Lake Erie and the latter opposite Port Stanley, the Niagara River, the western end of Lake Ontario and the eastern end where it discharges into the St. Lawrence River.

Special investigations of importance have been conducted opposite several large cities, notably those at Chicago and Cleveland. In 1924–25, the U. S. Public Health Service, in cooperation with the Sanitary District of Chicago, the Chicago Department of Health and the Indiana and Illinois State Boards of Health, carried on an investigation of the pollution of Lake Michigan in the vicinity of South Chicago and the Calumet and Indiana Harbors. Earlier investigations were made in 1908, 1909 and 1910 of this same portion of Lake Michigan and are published in the reports of the Lake Michigan Water Commission and the Indiana State Board of Health.

Three investigations of the quality of the water of Lake Erie opposite Cleveland and its suburbs were made in 1904, 1912 and 1920, respectively. The first investigation was made by the late Professor Geo. C. Whipple and was unusually exhaustive in discussing local conditions; the second study was made by Professor D. D. Jackson, of Columbia University, and the third by the writer. A second investigation of a limited area was also made by the writer in 1924, for the purpose of locating a proposed new intake for a new pumping station and filter plant for the city of Cleveland. An investigation in 1909–1911 by Alvord, Whipple and Eddy, consulting engineers for the city of Milwaukee, Wisconsin, included a study of lake currents in Lake Michigan opposite that city. Many other studies have been made for the purpose of determining local conditions of pollution and their relation to the best positions for the location of sewer outfalls and water works intakes. But the deductions which may be drawn from all the investigations which have been made clearly indicate certain definite conclusions and which may be briefly set forth as follows:

(1) That the waters of the Great Lakes are dangerously polluted with sewage along the shores opposite centers of large population, and that such waters should not be used for public water supplies without purification.

(2) That the dispersion of sewage and trade wastes from outfall sewers, the contaminated flood waters from storm sewers and the discharge of polluted rivers, is influenced primarily by the intensity, direction and duration of the

winds, by the contour of the shore line and by the slope of the bottom outward from the shore.

(3) That direct contamination of intake waters from passing vessels and from the dumping of material dredged from harbors and rivers, the waters of which are badly polluted, may be a source of danger to water supplies.

(4) That dilution of sewage and trade waste discharges with the purer water of the lake, and the accompanying biological factors tending to diminish the concentration of polluting matter, is an uncertain factor of safety, owing to the erratic and irregular diffusion of these discharges.

It may be well to point out more specifically the areas of gross pollution and to show how they are affected by lake conditions. For example, the city of Detroit and its suburbs discharge their untreated sewage into the Detroit River, which connects Lake St. Clair with Lake Erie, while the Niagara River receives the sewage of Buffalo and adjacent cities. In these rivers a well-defined current carries the pollution down stream into Lake Erie and Lake Ontario, respectively. Diffusion of the sewage, therefore, is governed largely by the factors exerted under stream-flow conditions. The western ends of these two lakes show the contaminating effect of these polluted streams for some distance from the mouths of the rivers. As the streams or connecting straits between these lakes are quite broad and the current well defined, sewage discharged from outfalls may be carried in stream lines without much diffusion for considerable distances. However, the action of the winds in setting up deflecting currents is not without its effect even here.

The conditions influencing lake water pollution opposite centers of large population, such as at Milwaukee, Cleveland, Toronto and many other of the larger towns and cities, differ somewhat from those described on the Detroit and Niagara Rivers. Dangerous contamination of shore waters in this case is produced principally by the irregular diffusion brought about by surface and sub-surface currents induced by wind action and other factors, as previously explained. Since these conditions are uncontrollable and difficult, if not impossible, to forecast, the danger of contaminating intake waters used as public supplies becomes a serious problem.

The movement of the water through the lakes is very slow. For example, with an assumed uniform flow in a cross-section of Lake Erie opposite Cleveland, the current produced would be 0.16 of a mile per day, if there was no wind acting to produce surface and sub-surface currents. This general drift of the water is negligible when compared with currents induced by wind action. It has been estimated that surface currents in the lake will have on an average a velocity of about 5 per cent. of the velocity of the wind. It is of course evident that the duration of the air currents in any one direction, as well as their intensity, will materially affect the water currents in the lakes. Onshore winds have a tendency to pile up the water along the shore, and it naturally returns as an undertow to the body of the lake. Under such conditions, it may be easily perceived how polluted water from the shore may find its way directly to water intakes, and how sewage from outfall sewers will be swept outward into the lake. On the other hand, offshore winds will carry the surface water away from the shore and will bring the purer water from beyond the zone of shore pollution toward the shore. Under such circumstances a purer water is more likely to be obtained at the intakes, although the outward flowing polluted surface water, unless rapidly dispersed, may be a source of contamination to intake waters even under these conditions.

Temperature changes in the waters of the lakes are also factors which modify the quality of the water at different periods of the year. At the bottom of a lake there is probably a stagnant layer of cold water which does not change much in temperature throughout the year. Variations in the temperature of the water in the zone occupied by the first fifty or sixty feet from the surface probably induce vertical currents. Since wind action is not likely to stir the water below a depth of fifty feet, it is apparent that all the factors affecting dispersion of polluted waters along the shore are most active within this zone, and which is probably fortunate from the view-point of rapid natural purification processes.

The chances of intake waters being contaminated by passing vessels are not as remote as at first thought might be anticipated. The enormous traffic on the Great Lakes means that a large number of vessels pass daily within short distances of water intakes. Polluted ballast water being discharged by vessels leaving or entering the harbors, and the sewage which they may discharge in passage, is a possible source of contamination, although regulations governing these conditions are supposed to be strictly followed. The entry to the lakes of ocean vessels from foreign ports, which will result in the greater use of the St. Lawrence waterway, opens up possibilities of the introduction of cholera and other water-borne diseases, unless the strictest enforcement of quarantine regulations is observed.

From the foregoing description of the physical factors affecting the dispersion of sewage, it is evident that erratic and uncontrollable conditions exist which can not be foreseen. They can only be guarded against by the careful purification of all the water drawn from the lakes for public supplies. Natural agencies for purification afforded by the dilution of sewage with lake waters are not dependable, although such factors should be considered in the design of sewage disposal plants.

The proper correlation of sewage treatment with water purification is always to be borne in mind in solving problems dealing with the waters of the Great Lakes. Adequate treatment of sewage and trade wastes is imperative, if water purification plants are not to become overloaded. Depreciation of shore properties for bathing and residence purposes, because of the washing up on the shore of floating sewage solids, of oil and grease, plainly indicates the need for adequate treatment processes for all sewage and trade wastes discharged into the lakes. A more determined effort to preserve these great inland lakes for water supply and recreational purposes by proper and effective methods of treatment of both sewage and trade wastes, is an obligation upon all who can speak with authority upon this important sanitary problem.

DISEASE, ITS CAUSE AND PREVENTION

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BACTERIA govern the length of man's life and determine the part of the earth on which he may live. They have defeated armies and destroyed cities; nations which have been the glory of the world have gone down before them. The majority of individuals born to-day would enjoy health and live to old age were their bodies not invaded by microbes. They are no respecter of persons, nor are they governed by the edicts of rulers. However, at the command of modern science they are commencing to relinquish their hold, and some of earth's most fertile regions, where in the past the risk to the visitor was greater than the visit to a battlefield, are being transformed into tropical health resorts. Some microbes are no longer the fairy-tale adventurers of death and disease. They are being controlled; disease is being reduced, and during the past century man's expectancy of life has been doubled. Still much remains to be done, for the learning and the practicing of the laws of sanitation can prevent more suffering and save more lives than the abolition of war. Here the scriptural entreaty is especially appropriate: "Give me understanding and I shall keep the law; yea, I shall observe it with my whole heart." Each bit of knowledge gained in this field carries man one step nearer the goal where he will be the master and not the slave of his environment.

The methods used in the prevention and cure of disease are determined by man's ideas concerning the nature and cause of disease. Man's earliest conception of disease was that it was due to demons. These were supposed to enter the body of their victim and rule in a merciless fashion.

> The possessed man, tossed and shaken in fever, pained and wrenched as though some live creature were tearing or twisting him within, rationally finds a personal spiritual cause for his sufferings. In hideous dreams he may even see the very ghost or nightmare fiend that plagues him. This is the savage theory of demoniac possession, which has been for ages, and still remains, the dominant theory of disease and inspiration among the lower races. It is obviously based upon an animistic interpretation, most genuine and rational in its proper place in man's intellectual history, of the actual symptoms of the case.

Such was the belief concerning disease amongst the early ancestors of modern civilized man, and such is the belief of primitive man even to-day. Logically, such a disease could be cured only by dislodging the invading demon, and what was more natural than to conclude that this could be accomplished by force or by flattery? The medicine-man attempted to force out the invader by making the habitation unbearable. The victims were whipped, loaded with chains, given ill-smelling and ill-tasting drugs, all in the hope that the demon would seek more congenial quarters. Often attempts were made to entice him out. Here charms, incantations and sacrifices played a prominent part. For centuries roots and herbs were prescribed because of their symbolic form. Curious things were used, such as moss scraped from the head of a culprit hanged in chains, or from mummies from the Egyptian tombs, or the roots of plants gathered in a graveyard during the dark of the moon. It was not until man discarded the belief that insanity is a manifestation of demoniac possession that the last vestige of the demoniac theory disappeared from the medical idea of civilized man.

Hippocrates, who is known as the

father of medicine and who lived during the fourth century B. C., was one of the first to teach that disease is due to a derangement of the body itself. He taught that the body contains four humors: blood, phlegm, yellow bile and black bile. When these were present in the right proportion, one enjoyed good health. Small variations accounted for differences in temperament; a sanguine temperament was due to a preponderance of blood; a phlegmatic to an excess of phlegm; and a bilious or melancholic temperament to a surplus of bile. Greater variations resulted in illness; hence, it was the object of the medical profession to keep the proper balance of the humors and in this way to maintain health.

Hippocrates' theories were not seriously questioned until the seventeenth century, when a flood of new theories burst forth. Some of those were even more complex and mystical than the ones they were intended to supplant. Disease was regarded as "an intestinal movement of particles," a "struggle between nature and disease-producing matter," a "lack of tone or an insufficiency of tone." There was the dynamic-organic system of Stahl, who believed that the soul was the supreme principle of disease. There was the mechanico-dynamic system of Hoffmann, which stated that life expresses itself in motion, and that all manifestations in the body are controlled by nervous spirits. The school of Montpellier taught that various organs possess individual life. Mesmer claimed that magnetic fluids flowed from the hand, and the Bremontau system asserted that all that was necessary for a cure was to determine the grade of a disease in accordance with the strength or weakness of the active irritation, and to adjust the right proportion of strengthening or weakening medicine to the case. The theory which lasted longest and had the greatest effect upon medical practice was the theory of homeopathy founded by Hahnemann (1775–1843). He defined disease as a "spiritual dynamic derangement of a spiritual vital principle." His theory was that the potency of drugs was increased by dilution, provided the dilution was accompanied by shaking. In some cases it was also supposed to be increased by pounding. Accordingly, he and his followers diluted their drugs to an enormous extent. They also tested them upon themselves. In the case of ordinary tinctures he recommended diluting two drops with 98 drops of alcohol, taking two drops of this mixture and adding 98 drops of alcohol, and repeating the process 30 times. Vershow commented on the folly of this doctrine by saying that he would defy even a German to detect beer at the mouth of the River Spree after a glass of it had been spilled into the river seven miles upstream. Hahnemann taught that in curing disease a knowledge of anatomy and physiology was unnecessary, and that pathology was a hindrance. Not only were the dosages he recommended always extremely small, but many of his preparations were of a highly poetic and romantic nature. There were: *Lachryma filia,* the tears of a young girl in great grief and suffering; *flavus irides,* the yellow rays of the spectrum, the extract of three kinds of lice, and the like. It is almost incredible that such a doctrine could exist, not to say flourish, for nearly half of the most progressive of all centuries. Yet it did, and was in the end actually an advance over some of the previous methods that had been emphasized in which prescriptions contained upward of one hundred ingredients. Some of the old prescriptions had been built up by succeeding generations of doctors, each doctor believing that he must add one or more drugs as his contribution to the prescription, or consider his life wasted. Thus, it is not surprising to learn that homeopathy cured more than the systems it was replacing. It appeared to substantiate the statement of Oliver Wendell Holmes: "If all the drugs that had ever been used for the cure of human ills were gathered together and thrown into the sea it would be ever so much better for humanity and ever so much worse for the fishes."

As is so well stated by Kopeloff:

> This maelstrom of confused theory was finally directed into a definite current. Louis Pasteur rose like a Triton. By the brilliance of his genius, by the clearness and breadth of his vision, he formulated the bacterial or germ theory of infectious diseases which must forever dominate medicine. No longer could malevolent spirits be held responsible for disease, nor could an improper admixture of the four humors be regarded as the cause of ill health. Disease was but another example of the struggle for existence. It was life preying on life; the invasion of the macro-organism by the micro-organism.

His first contribution was the discovery of the cause and method of prevention of pebrine, a disease of the silkworm and named from the black-pepper-like spots appearing in the body of the infected silkworm. It was undertaken by Pasteur in 1865 as a patriotic duty at the request of an old friend, Dumas, one who admired, had confidence in, and could foresee Pasteur's future greatness. For five years Pasteur struggled on without sufficient equipment, facing criticism and discouragement, suffering the loss of a kind father, of two loving children, and he himself brought near the brink of the grave by a cerebral hemorrhage which left him a cripple. In spite of these obstacles, Pasteur won. He found the black specks in the body of the diseased silkworms to be the cause of their death. He found that diseased moths lay diseased eggs from which developed diseased silkworms. These soon died or were useless in the production of silk. The germs left on leaves or in dust soon perished, but the ones in the eggs survived. Pasteur proved that the disease might be ended by the destruction of all diseased eggs. To this end he devised the process of placing each female moth when ready to lay its eggs on a separate piece of linen. After it had laid its eggs and adhered to the linen it was dried, removed from the linen, ground up in water, and the water examined microscopically. If black specks were present the eggs were destroyed; if not, they were kept and in due time yielded healthy silkworms. When the method was announced the cry came back: "It is impractical." To which Pasteur impatiently answered: "Don't tell me that any one wants anything simpler than a preventive method which is to just put your eye to the eyepiece of a microscope after pounding a moth in a mortar, with a few drops of water—mere child's play, taking an hour or two to learn." But the prejudice, falsehood and bickering were overcome only by Pasteur taking over an old, badly infected, valueless (in so far as the production of silk was concerned) plantation and transforming it into a profitable, productive, disease-free establishment. By so doing he demonstrated the practicability of his method, rescued the silk industry, and saved France something like four millions of dollars yearly.

The second disease to be conquered was anthrax, a disease highly fatal and widely prevalent among the lower animals. With man it is quite rare and less fatal. It is referred to in both sacred and profane history, modern and ancient. No one knows where or when it had its origin. Until the last quarter of the eighteenth century man stood in helpless astonishment before its rapid and fatal action. Its cause was the first organism to be seen by man, the first to be obtained in pure culture and one of the first to be conquered.

In 1877 Pasteur set out to discover a

cure or prevention. For years he struggled on. He traveled through infected districts, listened to the farmers' stories, studied its natural history. He grew the micro-organism in test-tubes and proved that it could be transferred from flask to flask and still produce the disease in susceptible animals. He subjected the organism to abnormal temperatures, injected it into the bodies of animals, and found that they did not contract the disease, but on the contrary such cultures rendered the animals immune. After repeated verification of the results, and after most careful analysis, he announced to the world that he had found a prevention for anthrax. His announcement fell on the ears of scoffers and skeptics. One veterinary journal in 1881 carried the following: "Will you have some microbe? There is some everywhere. Microbiolarty is the fashion; it reigns undisputed; it is a doctrine which must not even be discussed, especially when its Pontiff, the learned M. Pasteur, has pronounced the sacramental words, 'I have spoken.'" Ridicule, sarcasm and even personal abuse was not to deter the man who had fought through sorrow and illness and who knew that he had discovered a great truth. Great indeed was the astonishment and surprise when Pasteur announced that he would submit the question to a decisive public test. Fifty sheep were to be given the virulent anthrax bacteria. One half of them were to have been previously protected by the vaccine, while the other half were not. Pasteur predicted that the twenty-five unprotected sheep would perish, while the protected ones would survive. On May 5 the animals to be protected were given their first dose of the vaccine. Twelve days later they were given a stronger dose. On May 31 both groups were given the virulent anthrax bacteria. On the afternoon of June 2, the crowd, composed of farmers, veterinarians, physicians, journalists and scientists from near and far met to learn whether Pasteur was a dreamer or a prophet. What they saw was one of the most spectacular scenes in the history of peaceful science, a scene which Pasteur afterwards declared "amazed the assembly." Scattered about the enclosure, dead or dying, were the unprotected sheep. Twenty-two were dead; the other three survived only a short time. The vaccinated sheep were in perfect health. Thus was registered a victory of far-reaching importance in the conflict man is waging against disease.

This accomplished, he turned his attention to hydrophobia, that dreaded disease with a mortality of practically 100 per cent. and after years of careful, arduous labor, he prepared a vaccine which cut the mortality to less than 1 per cent.

For centuries some of the most fertile areas of the new world were uninhabitable to the white race, or if perchance any of this race settled in those regions, the appearance of yellow fever forcefully reminded them that they must move or die. Ninety times it invaded the United States, often enacting scenes which were the counterpart of the plague days in London. For four centuries the narrow Isthmus of Panama was regarded as the white man's grave. It is claimed that the first railroad constructed across it cost a human life for each tie. Ferdinand de Lesseps, who undertook to construct a canal across the isthmus, was forced to abandon it, not through lack of engineering skill, but because he did not recognize the part played by the mosquito. His men died like flies. Common laborers, nurses, doctors and engineers alike fell prey. One vessel brought over from France eighteen young engineers. Within a month after their arrival, all but one had died. Before the work was finally abandoned, thousands had lost their lives, and it was hard to keep enough well to care for the sick. Eighteen per cent. of all the men employed had died and many more were helpless. Twenty years later, due to the advancement of sanitary science, a canal was constructed and that with a mortality of slightly less than 16 per thousand! To-day the mortality is less in the canal zone than in many of our large cities. The cause is due to the discovery of the cause and method for control of yellow fever.

The discovery of antitoxin for diphtheria has reduced the mortality of this disease from 30 to less than 3 per cent. and the introduction of the toxin and antitoxin foreshadows its absolute control. The work of the Dicks bespeaks a similar victory over scarlet fever. Typhoid fever is all but controlled. Asiatic cholera and plague are fast being swept from the earth. Typhus fever and a number of other diseases are within the control of man. What are the methods by which man is accomplishing such marvels? They are based on five firmly established principles:

(1) The so-called communicable diseases are caused by micro-organisms which are the descendants of other similar micro-organisms. If these disease-producing micro-organisms are kept away from the body of man there can not develop within him an infectious disease, regardless of his physical condition. These micro-organisms always breed true, and it is just as possible to grow a crop of diphtheria germs, typhoid germs or tuberculosis germs as it is to raise a crop of potatoes; and the bacteriologist would be just as surprised to reap a crop of diphtheria where he planted typhoid as the farmer would be to harvest potatoes where he had planted corn.

(2) The great majority of microbes which produce disease in man multiply only in the body of man and lower animals; hence, when seeking the disease-producing micro-organisms for laboratory study, we turn to man and the things which he has handled.

The evidence is complete that the microbes which cause tuberculosis, pneumonia, influenza, cerebro-spinal meningitis, scarlet fever, typhus fever, smallpox, whooping-cough, gonorrhea, syphilis, malaria, yellow fever and sleeping sickness multiply only in the bodies of animals. It is also an established fact that the number reaching the body of the animal is no larger than the number that leaves the body of another animal. Consequently, the idea that disease breeds in filth is only a myth.

(3) Diseases are transmitted through direct contact or through the intervention of flies or food. In other words, the principal spreaders of disease are fingers, flies and food. Numerous disease-producing bacteria are found in the mouth of the ill and often apparently healthy individuals, and it is a matter of little difficulty for those organisms to journey from the lips of one individual to the lips of another. The ordinary drinking cup is only one of the hundred and one things which come in contact with the mouths of many individuals every day and serves as the means of transportation. Hence, the idea that diseases are transmitted in the air was disproved when it was found that smallpox, measles or even scarlet fever can be housed in the same hospital, or even in the same wards with other patients without danger of cross infection, provided the necessary precautions are taken to prevent the carrying of infection from one individual to another by the attendants. Even malaria, yellow fever and the bubonic plague, which seemed to settle from the air on whole cities at a time, are now known to be conveyed by insects, and not by air; and it was the conclusion of

the Influenza Commission, after its careful study of the great influenza epidemic which so rapidly spread over all quarters of the globe, that this disease also travels in a "pair of shoes" and not in the air.

(4) A high state of bodily health should be the aim of all, but it does not necessarily confer immunity to the communicable diseases. We should laugh to scorn the individual who to-day would advocate keeping in the prime of condition so that he might resist the bullets of the enemy. Yet, how many believe that general good health protects against infection? We need only use our eyes to become aware of the fact that the physically fit and robust fall prey to typhoid fever, smallpox, influenza and most other infectious diseases as well as the weaklings. One should keep in the best of physical condition, for it is not until then that life is really made worth living, but every one should learn that disease-producing organisms must be kept away from his body if he wishes to avoid infection.

(5) In some diseases, immunity may be acquired by a mild attack of the disease produced by vaccination; in others it may be transferred from one animal to another through the blood by means of so-called antitoxins. Smallpox used to be one of the most dreaded diseases; to-day it has disappeared from the properly vaccinated community. Typhoid used to be the great scourge of the military and often civil authorities, but it has disappeared from the army and navy and is so rare in large cities that it is not uncommon to find young doctors who have not seen a case of typhoid. Properly used antitoxins reduce the death-rate for tetanus and diphtheria from 30 to 70 per cent. to almost the vanishing point.

EUROPEAN AND AMERICAN POLICIES IN THE PACIFIC COLONIES

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THE traveler comes away from French Oceanie with most vivid pictures of vast precipices, towering monoliths, flashing lagoons, and the sweep of great waves and pounding surf upon dazzling coral reefs set in sapphire.

But there are less pleasant impressions, too, chief of them a brooding atmosphere of decay, flavored with tragedy.

One observes the pitiful remnants of native peoples on islands that once teemed with tens of thousands; the deadening influence of French bureaucracy in world-distant Paris on these far-away mystic isles; and the corroding effect of European influences (often good in themselves) when applied blindly to people whose attitude toward life and society was so altogether different. The natives were destroyed long ago, and those in power to-day must not be blamed for the errors of the past.

However, the highly centralized government of France necessitates that any important decision must be referred to Paris, where some stupid or indifferent clerk may pigeonhole documents or give decisions on matters of which he can not possibly form any adequate conception. Governors are changed far too often to secure well-planned results, and even when a governor is well informed and zealous to remedy affairs he is sadly hampered.

Fiji is an English crown colony, with a population nearly equally divided between the indigenous black-skinned Fijians of magnificent physique and equally black-skinned Hindus of altogether different physiognomy and build. At the present time it is believed that the melting away of the native Fijians has been checked and that they are now holding their own in numbers, with a prospect that they may gradually increase. If this comes to pass, and the Fijians are given a chance to gradually develop new industries and improve the old, the English rule of to-day will well justify itself.

At Suva I talked with a British sea captain who had just returned from a long visit to the Hawaiian Islands. He contrasted the energy and development observed at Honolulu with the inertia, indifference and economic backwardness of Fiji. According to him part of this was due to English conservatism, part to short-sighted colonial policies, and part to the jealous restrictions imposed by Australia. For example, a promising fruit industry had been ruined by Australian regulations designed to freeze Fijian growers out of their only market.

West and northwest of Fiji lie the New Hebrides, a group of large islands extending northward for several hundred miles. The natives are Melanesians, naked blacks who still practice cannibalism upon the larger islands. Secure in their densely forested mountains, they have been able to maintain themselves fairly well in the past by eliminating (and often assimilating) those who invaded their islands. However, the past few decades have witnessed a great diminution in their numbers.

The English have always admitted that they are the world's premier colonial administrators. To those who accept all such statements at face value it might be an eye-opener to visit the New Hebrides. The islands are administered under a strange governmental hybrid known as the Condominium, a joint arrangement in which both England and France share equally. Each country has a high commissioner and an equal number of deputies and native police. These officials are empowered to look after their own nationals only, to guard their interests and to protect the natives.

The New Hebrides are comparatively near the important French colony of New Caledonia, and French influence has always been strong in the islands. The way the Condominium has worked, British influence has waned and French prestige and strength have steadily grown stronger. Largely through the short-sighted jealousy and rabid racial prejudices of the Australians, British planters have been forced to sell out to French interests, until now nearly everything is in the hands of the French or those who have taken out French citizenship papers. For instance, on Segonde Channel only three English planters are now left where some years ago it was almost entirely in English hands.

Because of the Australian attitude English planters are not allowed to bring in outside labor from other parts of the British Empire, but are only allowed to recruit labor from the native blacks of the New Hebrides. For the most part the cannibals of Malekula, Santo and other islands are not enthusiastic about plantation labor and the planters are therefore usually shorthanded.

The French planters are allowed to bring in any French subjects, and therefore they bring in as many Anamese as needful. Of course the strictest supervision is exercised over the health, housing, sanitation, food and working conditions of these Anamese laborers, who are not only far better off than in their native land but are also better housed and cared for than most of the New Hebrideans working on British plantations.

Further north and slanting still more to the northwest lie the Solomons, a group of large islands stretching away for seven or eight hundred miles toward the equator. Most of the islands are colonies of Australia, but those at the north formerly belonging to Germany, Buka Buka and the great island of Bougainville, are governed by Australia under a mandate from the League of Nations.

The natives are Melanesians like those of the New Hebrides and have been long noted cannibals and head-hunters. The head-hunting voyages of the past have been stopped, but in the interior of Malaita, Choiseul and Bougainville life has changed but little from the days of old. These great densely forested islands have been very little explored and their lofty volcanic peaks, clothed with almost impenetrable jungle, have never been scaled.

Former German New Guinea includes not only the northeast quarter of New Guinea (the world's largest island), but also the Bismarck Archipelago, the Admiralty Islands, and Buka Buka and Bougainville of the Solomons. All this vast territory is held by Australia under a mandate from the League of Nations.

The people of this territory are blacks, Papuans and Melanesians, living much as those of the New Hebrides and Solomons. In the interior of New Guinea cannibalism and head-hunting are still rife.

The natives of the Solomons fall naturally into two groups: (a) the salt water natives, living on islets along the coast and nominally or actually christianized, and (b) the bush natives, who preserve the old-time ways and are either slightly or not at all influenced by the white man.

Let us see what the government is doing for the natives of the Solomons. There is a commissioner at Tulagi, and a few hard-working magistrates scattered along the coasts of these great island wildernesses. Each magistrate has a small detachment of native constabulary.

Each magistrate controls a small area about his post; the salt water natives of course, and perhaps also for a distance of ten or twelve miles back from the shore in some places, more or less in others. Within the sphere of their influence these magistrates keep order, punish crime, and are hard-working men making the best of a difficult situation. But when home politicians urge the impossible there follow such things as the massacre of the local magistrate, his cadet and fifteen native police in Malaita near Auki.

One of their chief duties is to collect a preposterous head tax of ten shillings, which the Australian government levies upon each man.

But the government does nothing to develop trade in forest products such as rattan, gums and resins, or other resources of the islands, or to improve the native agriculture or mode of living.

When I asked "How do you expect these naked savages to pay such an outrageous tax?" I was blandly told, "Why, that is perfectly easy! All they have to do is go work on a plantation."

In other words the government head tax is a device for compelling the natives to work on plantations. It would not do to develop any native trade in forest products or otherwise make them financially self sufficient.

I do not mean to imply that this has all been worked out consciously or maliciously. To a large degree this policy is due to sheer stupidity and ignorance. Both in the Solomons and New Guinea various planters and government officials alike were amazed when I brought up the matter of trading in rattan, copal and other products. "Why, would anybody buy rattan?" was the reply I got over and over.

Rabaul, on the large island of New Britain, was the capital of German New Guinea, and is the capital of the Australian mandated territory. In the vicinity of Rabaul one gains an insight into the results of the German policies as contrasted to those of Australia.

"These natives around Rabaul are all too rich; they'll not work for any one" was what I heard several times.

Why do the Australians call them too rich, and where did they acquire their riches?

The German administrators were highly trained men of vision whose gaze encompassed the future. At their settlements permanent public buildings, docks and roads were constructed and everything prepared for development of the country and its resources. Each native householder was compelled to plant a few coconuts each year upon his own land, and each village was required to construct a certain section of permanent road. These were often high-handed measures.

Sixteen years ago the war gave the Australians a chance to grab German New Guinea, but the natives in the Rabaul region have copra to sell. This gives them money for cloth, knives and other tools, kerosene, tobacco and for their head tax. The roads unwillingly built under German rule give them easy communication. Their gardens and the sea supply them with most of their living. They are "too rich" to work for others.

All the public improvements and development in the New Guinea mandated territory date back to the Germans.

The planters of New Britain and adjacent islands get most of their labor from the mainland of New Guinea, particularly along the Sepik River and some of its tributaries. They ascend the Sepik for a hundred and fifty miles or more in search of recruits.

About a hundred miles up the Sepik I met a cultured young Englishman who put the situation well. He said: "These people do not need us at all. They are perfectly independent of the outside world and are better off without us, but we can't get along without them."

Everywhere in New Guinea one sees a wealth of rattan and other forest products utilized by the natives but otherwise untouched. As the people have nothing to sell, every able-bodied man and boy is compelled to contract with some planter to get tax money. The result is that in many villages there are only women and girls, old men and young boys; every lad over fourteen or fifteen and every able-bodied man has left. Accordingly the native life decays, the old laws fail, and nothing effective has been introduced to take the place of the old culture.

As positive accomplishments in New Guinea we may list the following: Suppression of head-hunting and cannibalism along the sea coast and for about two hundred miles along the banks of the Sepik River; suppression of the trade in crowned pigeon crests and bird of paradise plumes, thus preventing the rapid extinction of these birds of wondrous beauty; better control of labor recruiting and elimination of its most glaring evils; establishment of a school at Rabaul where Papuan boys are trained as plumbers, carpenters and the like. These boys are in demand on plantations, where they receive a pound a month and are the aristocrats of native labor.

Against these we may place the lack of vision to encompass a future for the natives other than as plantation hands; failure to work out a plan for improving the standards of living and economic status of the natives by bringing in new food plants or improved varieties of old ones; failure to provide a system of agricultural education for the natives; failure to lead the natives to the commercial utilization of forest resources; failure to develop transportation facilities; and lastly, a fault only too evident in our own country, too much political pull in certain government appointments.

When one enters Dutch New Guinea he encounters an altogether different atmosphere. Little coasting vessels creep into every inlet and from every village draw a store of rattan, copal, dyes, parrots, curios, button shells and other forest and sea products. These are forwarded to Makassar, Batavia and Singapore to be utilized there or sent on to other countries.

Instead of a head tax of ten shillings, the Dutch tax is two guilders, or eighty cents of our money. Furthermore, the assistant resident said that where there was little to sell as yet or for various reasons times were bad, the tax was reduced or even waived altogether. In recently organized villages, or where the wild people of the interior were just coming under governmental influence and as yet unused to the new ways, no attempt at all was made to collect a head tax.

West from Papua stretches three thousand miles of Dutch territory inhabited by Malays, heirs of an ancient culture in regions like Java, Bali, and parts of Sumatra and Borneo, still savage in the interior of Borneo and portions of other great islands.

The colonial work of the Dutch among these people is of course well known and dates back for centuries, when they wrested this rich region from the Portuguese. The Dutch policies have undergone great liberalizing during the past few years, and the welfare of the native peoples is cared for by a body of extraordinarily well-trained, competent and devoted civil servants.

It is the policy to retain the land for the natives, improve their economic status, give them a certain amount of academic education in the vernacular, and look after public health and the interests of the natives generally, while encouraging the investment of foreign capital, the development of plantations and the introduction of new industries. Higher education is also provided for the wealthy and for brilliant students able to profit by it.

British North Borneo is a rather unique colony in that it is owned and governed by a private company. There is a scanty native population along the coast, and the rest of the natives live, for the most part, a long way inland. In consequence the government has encouraged the immigration of Chinese, mostly Hakkas, so that the capital, Sandakan, is almost a Chinese town.

The governor is a man of ideals and vision, and he and his staff, freed from the incubus of satisfying home politicians, are able to plan and work in such a way as to safeguard the landholdings and future of the natives. Conditions are therefore far superior to those in the colonies and mandated territory under Australia.

The difficult problems constantly arising in the administration of agricultural lands, forestry, relations of the various native groups with one another and with the whites and Chinese, are studied and acted upon with great care so that admirable progress has been made along these lines.

Not much can be said for the development of roads and land transportation, or of education. The fact that a considerable number of Filipinos are employed by the government of British North Borneo, along with a scattering of Hindus and an occasional Chinese, with a few whites in the key positions, is sufficient commentary upon the status of education in the colony.

In the Philippines we again enter islands where the native population has been in contact with higher cultures for many centuries, and where by far the greater part of the population has assimilated more of European culture than any other people of the tropics. The Spanish christianized the great bulk of the people, and in many ways brought them to a higher level than the other Malays.

After centuries of Spanish rule, the Americans stormed the "Pearl of the Orient" and proceeded to do things never before attempted in the tropical possessions of any European power. Mass education of all children, not alone those of the aristocrat but of the farm laborer, fisherman, Mohammedan and pagan, was begun. Many new things were introduced, such as public hygiene and sanitation, good roads, pure water supplies, sewers and docks.

Errors, blunders and stupidities there were in plenty, some comical or ridiculous, others pitiful or even shameful. But in spite of all mistakes both of omission and commission, the fact remains that as a result of policies begun under American control, encouraged by Filipinos like the late Dr. Pardo de Tavera, and in many cases ably continued by Filipinos trained in the United States, general conditions in the Philippines are superior to those in any other region of the tropical Pacific. The general level of education is far higher than in any of the other regions mentioned here, and the desire for education and cultural progress is nation wide in the Philippines.

No one is better aware than the writer of the shortcomings of the past thirty years in the Philippines, and no one has been a severer critic of certain features of the policies pursued and their harmful effects upon both Filipino and American welfare. In spite of this I feel certain that no student of economic and political conditions can visit a series of tropical colonies and compare their status with the results attained in the Philippines and not recognize at once the superiority of the latter and the higher level of the Filipinos.

It would be futile to point out here mistakes made by both American and Filipino leaders, which a larger vision would have shown to be detrimental to the ultimate welfare of the great mass of people concerned. I shall merely state that the higher cultural and educational level attained by Filipinos in general places them in a different class from the natives of any of the colonies here considered. The fact that Filipinos are called upon to take over responsible work in government offices in various colonies outside the Philippines is sufficient to prove the statement. The fact that in the Philippines practically all governmental activities are conducted by Filipinos is not only a testimonial to their ability but is also ample justification of the general idea underlying American policies and of American faith in the Philippine people.

Every one conversant with conditions in the Philippines agrees that their present status can not be continued indefinitely. It is not just and fair to either Filipinos or Americans, whether their interests agree or diverge. Sooner or later Congress should decide the future of this wonderful group of islands, and in fairness to all concerned the sooner it is done the better. I, for one, am certain that many factors are slowly but surely paving the way to the complete independence of the Philippines. No matter what obstacles are placed in the way of this attainment and no matter how honest or sincere the opponents of independence may be, nothing can prevent its ultimate achievement.

PSYCHOLOGICAL ASPECTS OF CALENDAR REFORM

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In the efforts made to reform our lopsided calendar, too little consideration has been given to the principles of psychology. The popular mind clings to tradition in the fundamentals of life, as shown in our persistent cleaving to our bewildering system of weights and measures, and the British adherence to their inconvenient monetary system. It often requires a social cataclysm, like the French Revolution, to uproot these traditions.

An added difficulty arises in the case of calendar reform, due to religious doctrines and prejudices. In Christian, Jewish and Mohammedan countries the 7-day week, with its one day of rest, has been recognized from "time immemorial," and any attempted dislocation of this cycle inevitably meets violent opposition. The real problem, then, is how to overcome this popular inertia and religious protest.

Of the two proposed schemes, the 13-month year and the smoothened 12-month year, each has certain advantages. It is easier to associate day and date in the 13-month scheme, since these are the same in every month: the 7th always falls on Saturday—the 13th is always a Friday. In the 12-month calendar one has to remember three associations: in the Swiss calendar, for instance, the 1st of the month is Monday in January, Wednesday in February, Friday in March; Monday again in April, and so on—a very simple and easy reckoning compared with our present calendar, where no one but an expert can tell on what day the 12th of next October falls, or the date of Labor Day, or when school or college will open next year.

To those who receive weekly wages, 13 months of four weeks each seems preferable; while those on monthly schedules naturally prefer the 12-month division. For business and finance the latter has the advantage in reckoning quarterly and semi-annual earnings, in making quarterly dividend and semi-annual interest payments, and in making out and posting a lesser number of monthly bills. The four seasons fit better into the 12-month scheme too. An objection to the 12-month year is the thirty-first day that is added to one month in three, making the length of the months irregular. But this offers no real difficulty. According to the Swiss project, each quarter begins on a Monday; the third month with 31 days has five Sundays, so that it has the same number of work-days as the other months.[1]

Taken on its merits alone, the 12-month year works better. But even aside from this, it is preferable for psychological reasons. The community at large looks askance at a new month, as it does at a milligram and a kilometer. It will take an immense amount of pamphleteering and magazine-work to reconcile the public to such a drastic innovation. On the other hand, a mere rearrangement of length in the existing months should meet with comparatively little opposition, when the many advantages of this evening-up are pointed out.

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[1] In the Swiss scheme the months of each quarter are given 30, 30, 31 days. In the World Calendar they are arranged 31, 30, 30, but the number of working days is the same in each month, since the 1st of January is Sunday. My preference for the Swiss plan is largely for historical reasons.

The main obstacle to calendar reform comes from the 365th day, which throws the weekly sequence out of gear. Either one must begin each successive year on a new day, or else one must somehow "take a day off" every year—and two days off every fourth year. Here the reformer runs up against an even more powerful psychological factor: there is not merely passive inertia but active opposition to the proposed change. If the 7-day week has been divinely ordained, what is man that he should dare disturb the sacred cycle?

The force of this objection, as a factor of folk and religious psychology, has undoubtedly been underestimated by the calendar reformers. The church—whether Christian, Jewish, or Mohammedan—is a powerful institution in our present-day civilization, and unless its influence can be enlisted in behalf of the movement, the reform has little chance of success. Certain prelates, as individuals, have or can be won over; but so far as I know the ecclesiastical authorities are loath to lend official support.

What antagonizes especially the religious sense of the community is the idea of a "day without a name"—a *blank* day inserted, say, between Saturday and Sunday, which lengthens one week every year to an 8-day cycle. Does not this fly in the face of divine ordinance as well as of age-long custom? Is there any possible way of getting around this impasse?

For many years the calendar and its eccentricities fascinated me. In the 1890s I devised a simple mnemonic formula for calculating the day of the week for any date, past or future, on the Gregorian system. Later, I constructed a fairly simple universal calendar with circular disks, which could be set for any year and month. The scheme of calendar reform proposed in 1900 by L. A. Grosclaude[2] struck me as rational and feasible, apart from the ecclesiastical objection, whose importance was obvious to a psychologist. Some several years later a possible way of meeting this objection occurred to me. Instead of having a *blank* Year-Day, each year, why not give it a name? If the new calendar were put into operation, say, in 1932, let us call the Year-Day of that year *Year-Sunday;* the next year (1933) the Year-Day is called *Year-Monday,* and so on. Thus at the end of every seven years we have a *week* of Year-Days, which follows, at least in principle, the traditional 7-day cycle. And the same may be done with the Leap-Days. If Leap-Day in 1932 is designated as Leap-Sunday, then Leap-Day in 1936 is Leap-Monday, and so on—again a 7-day cycle.

Such was the device that occurred to me as a means of overcoming religious scruples. It follows the main plan of the Swiss (Grosclaude) calendar—an ideal system for reckoning weeks, months, and days—and at the same time it preserves the weekly cycle, though in a novel way. My plan was described in a *Science*[3] article published during the World War. At that time many of us expected that a notable social reorganization would result from the war; and to me at least the time seemed ripe for calendar reform. But, here again, the psychological factor was not sufficiently taken into account. I had no leisure to start systematic propaganda; the *Science* article, the numerous offprints which were sent out, and desultory personal efforts by the author, failed to enlist a vigorous champion of this plan. When interest in calendar reform revived it followed other directions. Why? Because those other systems had active promoters, who carried on the campaign along carefully prepared, strategic lines. This is excellent "psychology."

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[2] See *Revue Scientifique,* 1900, 4ᵉS., vol. 13, p. 766.

[3] "A Common-Sense Calendar," *Science,* n. s., 47: 375–377, 1918.

The reader will note an apparent contradiction here. I started out by suggesting that the advocates of calendar reform were rather blind to the principles of human psychology. And now they are commended for using good methods of applied psychology. But the contradiction is only apparent. It is one thing to excite attention—quite another thing to induce acceptance; for attention may produce opposition instead of conviction. Unless the arguments for reform are so powerful as to sweep aside such opposition, the movement is bound to fail.

The psychologist would urge the reformers, first of all, to present a united front. Let them agree on either the 12-month or the 13-month calendar. But let them *unite*. An equally important step is to enlist the active support of ecclesiastical authorities in the leading religions and sects; for their influence counts more than any other single factor. The industrial and financial leaders too must be enlisted—not merely as supporters but as active workers. And our educational leaders should be brought into the fold—for what school or university or professional institution is not vexed by the wanderings of the "academic year"?

The ecclesiastical authorities will be hardest to reach. It is true that the present calendar bears the name of a distinguished pontiff. But his reform involved only a slight dislocation of the Julian calendar. The church will not readily accept a change which involves altering many feast-days, fasts and saints-days. The tremendous value of the new system must be made clear beyond peradventure. I am inclined to doubt whether this can be done without adopting the device of the Year-Week and the Leap-Week, with its compensatory Year-Sunday and Leap-Sunday, which round out the age-long 7-day cycle. Even this may not meet the prejudices of certain strict constructionists. But all others can be brought into the fold if the advantages of the change are made evident. For "the Sabbath was made for man—not man for the Sabbath."

To sum up: It is not sufficient to agitate for reform. The appeal must be made to this, that and the other individual and class of society. There are abundant arguments for calendar reform, one or another of which should strike home to almost every group in the community. The best strategy is to attack each group or class with those particular aspects of the reform which will affect and improve their own situation.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

HOW INSECTS AFFECT OUR HEALTH AND COMFORT

By F. C. BISHOPP

BUREAU OF ENTOMOLOGY, U. S. DEPARTMENT OF AGRICULTURE

INSECTS are man's most relentless foes. They oppose him as he struggles to release a few acres of farm land from the grasp of the wilderness on the frontiers of civilization. They attack him with deadly effectiveness as he enters the unexplored jungles of the tropics in pursuit of gold or game. They greet him with their million vicious stings as he tramps the tundra of the great Arctic region. They contest his rights to live peacefully by the tilling of the soil in the fertile valleys and plains of the world. Even in the great cities where man appears to have thoroughly conquered nature, the persistent army of insect foes devours his foodstuffs, eats holes in his Sunday-go-to-meeting clothes, accompanies him to his work in the seams of his garments, or sallies forth at night from his mattress or flies through his unguarded window to satisfy gluttonous appetites on his very life blood.

In the meantime the trench diggers of the insect army are mining beneath his garden and stealing the products of his toil, while others far from the habitations of man tunnel and kill his great forest trees. Even the timbers of his house crumble under the attack of the hidden hordes. In true war-time fashion, one division of the army strikes at his lines of communication by weakening the telegraph and telephone poles, while another actually burrows through the lead cables and throws whole systems of communication into chaos. With all the millions of dollars of loss caused by our innumerable insect foes, I would not have you think that all bugs are bad bugs. We all remember our indebtedness to the honeybee and the silkworm, but we may forget the vital part which insects play in helping us to produce our fruit and other crops by fertilizing the flowers and in directly attacking and destroying countless numbers of destructive hordes. This interesting and important rôle of the deserters and revolutionists in the insect army is well illustrated by the oft-repeated ditty:

> Little fleas that do us tease
> Have other fleas that bite 'em,
> And these in turn have other fleas,
> And so *ad infinitum.*

When each of you comes to understand more fully the size and might of the insect army, the thousand and one ways in which this army is recruited, its diverse and subtle methods of attack and the intricate defenses which nature has thrown up to protect some of her works from the destructive forces of others, you will see more clearly the need which man has for a considerable number of workers to study the strategy of the invaders and to forge effective weapons of defense. One of the largest and best trained and organized armies ever developed to oppose these insect invaders is now on the firing line in the Bureau of Entomology of the United States Department of Agriculture and in the entomological units of the various state experiment stations and other state organizations. And the U. S. Public Health Service gallantly occupies certain sectors of the front, especially in offensive operations against mosquitoes. One of the eleven divisions of the Federal army of entomologists of the Department of Agriculture is directing its efforts against the insect foes which directly affect man and his flocks and herds. The tactics and types of troops employed by the enemy cohorts with which this division of the bureau is engaged are extremely varied. Some, like the house fly, pick up and put on the food and in the milk such dangerous germs as those of typhoid, dysentery and tuberculosis. Others, such as the mosquitoes whose surname is Anopheles, serve as incubators for the malaria organisms and without these mosquitoes this disease could not survive or spread. Certain diseases are introduced into the blood of man or domestic animals by the bite of a bug or tick, while the germs of others may be deposited on the skin while the insect is feeding and then gain entrance to the body through a puncture made by an insect or through injuries made by scratching. Some insects harbor the young of dangerous parasitic worms which find their way into man or animals through the bites of these insects or through the visitation of open wounds by them. Sometimes a bird or other animal will eat these worm-infested insects and thus itself become infested.

Many of the insect army are not given to carrying diseases but sally forth with lance-like beaks or poisonous stings. Others of the army refuse to fight in the open, but invade the skin of man and his faithful animal friends and make life intolerable by the persistent itching which they cause. There are biters whose juices blister the skin; caterpillars with hairs more venomous than the fangs of the rattler; wasps and bees with vicious stings; blood-sucking flies with beaks like a hot needle. Then there is the almost omnipresent maddening hum of mosquitoes large and small punctuated by their stinging bites. The dainty but heartily cursed sand fly, which mocks the mosquito hovering outside the screen, climbs nimbly through its meshes and indulges its appetite on the infant's dainty blood. Nor will the elusive flea forego his desire to keep in the spotlight of our attention, though we have largely relegated the disgusting cootie to the poorer and more crowded quarters of our towns and cities and to the unfortunates who inhabit these places. In the meantime the eight-legged relatives of the insect hordes, the irritating chiggers and ticks, would by united attack drive us from our favorite woodland haunts and grassy dells. Again, the enemy, in the guise of flies with brilliant green uniforms, lays eggs on wounds and the resulting maggots cause disfigurement or death by their gnawing.

And speaking of this group of scavenger flies, here is a very remarkable and interesting thing. Since the war Dr. W. S. Baer, of Johns Hopkins University, has found that the young or maggots of the flies can be made to work for us in a way that promises to be of untold help to suffering humanity. In hospitals and elsewhere the surgeons are beginning to use them to clean up the diseased material in certain grave bone troubles and to stimulate normal healing.

The outcome of the battle against the multitudes of hostile insect warriors lies largely with you. After all, the entomologist is only the sentinel on guard, the scout to find where the enemy lurks, the strategist to determine the weak places in the army's defense and to map out the plans for breaking down its offensive: the directing officer to assemble the opposing army and the munitions of war. But you, the householders and farmers and manufacturers, make up the rank and file of this army and must do the fighting if victory against the insect host is to be won.

When the foe is a new invader the government and state forces, by concentrating all efforts on complete extermination, as in the case of the recent battle so decisively won against the Mediterranean fruit fly, may with your support and cooperation carry the day. But extermination is neither practical nor possible in most cases. These foes must be met on a hundred fields of action day after day—year after year. Many of the plans of defense are not yet well worked out by the entomologist; the problems are formidable, their solution is difficult, and your patience and support are craved. The tactics of many divisions of the invading army, however, are now well known and the plans of offense well worked out. Some of these call for you to enter the trenches and smoke the enemy out and thus forestall his offensive. In fact this is the strategy which must be employed against many of our foes. To succeed in economical production of live-stock, dairy products and poultry, to reduce to a minimum the dangers of insect-borne diseases, to avoid annoyances due to pestiferous insects, you should know your enemies—know your bugs. The Bureau of Entomology is ready to prepare you for a successful combat against many of those pests which worry your live-stock, reduce your income and interfere with your comfort and happiness.

SEA BEACHES AND THE TIDE

By Captain **PAUL C. WHITNEY**

CHIEF, DIVISION OF TIDES AND CURRENTS, COAST AND GEODETIC SURVEY

THAT so many people select the sea beaches for their favorite summer vacation retreat may have an origin in the geological past when we, as denizens of the deep for countless generations, lived and died between the tidal levels and in the shallow warm waters of the ancient seas. Thus our present love for the ocean may result from a slight homing instinct carried down through the ages.

The beach is nature's perpetual battlefield where relentless war between land and sea is waged without truce, and where either side may gain or lose according to local circumstances. It is always a source of delightful new experiences. Each day we can make a new find or observe something of nature that opens new vistas of our wonderful world. At high tide or at low tide, after a storm or even during calm weather there is a new shell to pick up or a bit of drift, around which to weave a story. Its fresh salt air acts as a tonic after months spent indoors, and a few days' communion with the sea is good for us, both spiritually and physically.

There are several types of sea beaches. The sand beach is usually the mecca of the summer tourist and is of course the only beach where ocean bathing can be thoroughly enjoyed. To those of us who enjoy nature and the many manifestations of her handiwork, the sand beach has many interests other than of bathing and the latest styles. The booming surf, bringing its message of distant storms, is of constant interest and never twice alike. The destructive power of the breakers can be seen any time during one of the heavy northeasters that occasionally visits our eastern coast. These storms are generally accompanied by unusually high tides and are awe-inspiring in the extreme. The constant play of the surf day after day, year after year, finally works the largest rock debris into the fine grains of sand that are a part of the present beach.

Some sand beaches pack smoother and harder than others, and the shape and composition of the sand grains that make up each beach have a great deal to do with this condition. Daytona Beach, Florida, where all the fast automobile records are made, is perhaps the finest example of a smooth, hard beach. The advantage of such beaches over man-made roads for speed trials is that no matter how smooth the road was originally, time and traffic are bound to leave their mark; as for the sand beaches, each flood tide recreates their original smooth surface.

There are many forms of life present on a sand beach at low water and if any one has an idea that a crab is slow, let him try to catch a fiddler crab before he darts into his sand hole. The lace-like jelly-fish, in some places known as the sea nettle, a beautiful creature when drifting around in his own environment, is not a thing of beauty when thrown upon a beach and left by some retreating wave. With no supporting bony structure of any kind, the jelly-fish is so low in the scale of life that it even looks up to the lowly earthworm. Nor does it suggest as a mass of red or clear jelly its special stinging defence that many a bather has experienced when in contact with one.

The clam is another inhabitant of the sandy beach, and the pure white shell of some New England clams was the reason for the old belief that "they fed only on white sand." The picturesque clam digger as he solitarily bends over his labor has been described by many writers. The sand clam is dug during low tide and at this time its presence is sometimes indicated by a spout of water as one walks nearby. The razor clam is long, narrow and sharp on the edges and is able to descend in the sand so fast that one must dig quite rapidly to catch him. As the clam feeds during high water and then is also safe from the clam digger, the old saying, "as happy as a clam at high tide," probably is true.

The searcher may some day be rewarded by finding a piece of ambergris, that tallow-like substance supposed to be formed as the result of a disease of the sperm whale and when cast out by the animals floats on the surface of the water until thrown ashore on some beach. It is used in the compounding of perfumes. Masses of over 100 pounds have been found and as it is worth many dollars an ounce, a find of a large piece means a fortune to the lucky finder.

And the rocky beach, hard to walk along, but of greater fascination, perhaps, than the sand beach. Here we find rocky cliffs being eroded by the tremendous cutting and undermining powers of the surf breaking at their bases, and the debris from this losing battle strewn about in various shapes and sizes. On the rocks, uncovered during the lower tides, we find mussels growing in great quantities; and the tiny shellfish, known as the periwinkle, good to eat when boiled and you are very hungry; or the five-pointed starfish, one of nature's early experiments in evolution and perhaps the forerunner of our five-fingered hands. Children like to dry them out and take them home where they finally find their way to the attic along with the old family album. The sea-urchin, another curious product of nature's workshop, has a ball-shaped shell, covered with spines. Sea-urchins are not appetizing-looking, but the sea-gulls apparently know better as they carry them from their rocky homes to lofty heights and drop them to break their shells. These broken shells are not uncommon on the beaches. Frequently whole dried shells are cast up and their dome-shaped symmetrical outlines are very pleasing.

Another beach, but found only in the

southern waters, is the coral beach. This strand is composed of coral debris, of finely divided matter from the skeletons or limestone framework which serve to support the coral animals while they are living. Such beaches are gleaming white in the midday sun. Just outside of the low water fringe, an observer may see the protruding tops of living coral communities. These never attain a height above the plane of mean low tide and serve to maintain the large supply of material which is continually being ground up by the action of the waves. The skeletons of coral polyps are found in various shapes and their characteristic forms give rise to designating names, such as mushroom coral, fan coral, tree coral, bud coral, brain coral, etc. To get the full effect and beauty of growing coral, one must find a sheltered coral lagoon and in a boat on a calm bright day drift slowly over it. This undersea scenery is magnificent and a woodland glade is no more beautiful than the effect from the sun shining through the clear water, lighting up the various coral branches and shapes with the highly colored tropical fishes swimming lazily about.

One striking feature of the sea beach is the daily rise and fall of the water, known as the tide. The regularity of this ebb and flood was thought by the ancients to be caused by the breathing of some mighty animal supporting the earth. Our present knowledge tells us that it is the natural result of the tide-producing forces of sun and moon acting on the waters of the ocean. As the daily positions of these bodies are known in advance, their combined effects on the waters of the seas can be predicted. The mariner, as well as the yachtsman, the fisherman, the bather, the engineer and others, often desires to know in advance the state of the tide, and to supply this information the Coast and Geodetic Survey, through its division of tides and currents, annually publishes in advance tide tables that give daily predictions of the times and heights of high and low water along our coast as well as foreign ports. These predictions at one time involved long and laborious mathematical computations, but are now made on the survey's tide-predicting machine, a marvel of mechanical skill and mathematical ingenuity. Visitors to Washington are cordially invited to the Coast and Geodetic Survey where they can see this machine at work. Right now it is busy predicting the tide at Nagasaki, Japan, for the year 1933, where the tide has a rise and fall of about 5½ feet; but it predicts with equal ease the tide in Cook Inlet, where the range is 30 feet and more.

Giving advance information of the rise and fall of the tide is not the limit of this robot's ability. It also predicts the times and velocities of the tidal current and these are given to the public in the form of current tables, and like the tide tables are annually published in advance.

In closing, I wish to call special attention to the fact that although the tide and tidal currents can be predicted, there is that uncertain current in and just outside the breakers called the undertow of which there is little definite information. Its strength of flow is probably due chiefly to the angle the advancing wave-fronts make with the beach. This current, under certain conditions of surf and wind, transports large quantities of sand from one location to another along the coast, and, together with the waves that are produced, is probably the most important agency contributing now to shore-line changes. To the inexperienced swimmer this current is a grave hazard, and he must be careful to keep out of its influence or possibly be rapidly carried beyond his depth. Its neglect can be the cause of many drownings.

THE ROYAL SOCIETY OF LONDON AND ITS INFLUENCE UPON SCIENTIFIC THOUGHT IN THE AMERICAN COLONIES[1]

By FREDERICK E. BRASCH
CHIEF OF SMITHSONIAN DIVISION, LIBRARY OF CONGRESS

(*Continued from the October issue*)

IN the further study of colonial scientific contribution to the Royal Society we now come upon one of the most interesting of men, namely, John Mitchell. The life of this scholar is devoid of the essential facts relating to his early life and education, but his later years are full of successful and manifold activities, of which he left abundant record. Mitchell was born in Scotland and was educated for the career of medicine, and came to the colonies about 1700 and settled in Virginia on the banks of the Rappahannock River in Urbana.

Mitchell's great interest in science is evidenced by his rich contributions to the study of electricity, botany, medicine, agriculture, history and cartography, a detailed account of which, however, would be beyond the capacity of this paper. After nearly fifty years of residence in the colonies, Mitchell returned to London, in 1746, and was made a member of the Royal Society by being elected a fellow on December 15, 1748. He never returned to the colonies, but died in London in 1768 of an illness which he had contracted in Virginia.

By virtue of his scientific training, Mitchell was eminently fitted for pioneer research work, as his powers of observation were keen and his deductions accepted by the leading scholars of Europe. Due to his skill he was able to make great botanical collections, and this material was highly appreciated by those to whom it was sent, as is evidenced by his voluminous correspondence with such scholars as Sir Hans Sloane (president of the Royal Society), Peter Collinson, Linnaeus, Gronovius and Dillenius.

Mitchell had early recognized the merits of Linnaeus' system of the classification of plants and had mastered its technical details, and it is to this fact that he owes a large measure of his success as a botanist. The first of his writings to be published of which there is any record is entitled "Dissertatio brevis de principiis Botanicum et zoologorum," written in 1738 and dedicated to Hans Sloane. This was followed in 1741 by another botanical paper, "Nova Plantarum Genera." These were offered for publication through that clearing house of botanists conducted by Peter Collinson in London. The second paper was dedicated to Collinson. In the latter publication Mitchell describes 30 new genera, of which twenty-four were proposed as new; nine certainly were original and have been confirmed as true genera by subsequent botanists. Two years before he went to London he visited John Bartram and Benjamin Franklin in Philadelphia. With the former he discussed botanical problems and with the latter the details of the infant science of electricity. Early in 1746 he sailed for England with more than a thousand specimens of native plants. Mitchell lost all his belongings, however, when the ship was captured by Spanish privateers, and it was not until many months later that his collection found its way back to him, but in a ruined condition, "to the great misfortune of botany,'' as stated by Linnaeus. He attempted to renew his collection with fresh specimens and seeds sent him by Bartram, with whom he continually corresponded.

In 1744 he wrote a lengthy report on the epidemic of yellow fever which prevailed in Virginia in the years 1737, 1741 and 1743, giving his observations on the many cases which he treated. This paper was given to Benjamin Franklin to be presented before the new scientific society called Junto which Franklin had just formed in Philadelphia. As was the custom at that time, Mitchell's paper was referred to Dr. Cadwallader Colden, of Albany, for criticism. This report, together with Colden's letter of comment, came into the hands of Dr. Benjamin Rush some years later and formed the basis of his treatment of an outbreak of that disease which occurred in Philadelphia in 1793. This paper of Mitchell's was finally published in volume 4 of the *American Medical and Philosophical Register*.

Mitchell's first paper[27] to the Royal Society was in the form of a letter to Peter Collinson, from Urbana, Virginia, April 12, 1743, entitled: ''An Essay upon the Causes of the different Colours of People in different Climates.'' This lengthy essay was demonstrated in seven propositions and is based mainly upon the philosophy of Sir Isaac Newton concerning the causes of color. It concerns the color of the white, black and yellow races, as he found them in the American colony. His essay on ''An Account of the Preparation and Uses of the various Kinds of Pot-ash'' followed and was read on November 17 and 24, 1748. In this paper[28] he enters into a discussion on the great economic value of potash and methods of preparation in vogue in the various countries of the world. His next communication to the Royal Society was a letter addressed to Dr. Birch, the secretary, ''concerning the Force of electrical Cohesion.'' He also presented to the Royal Society one of Franklin's first papers which was entitled ''Sameness of Lightning and Electricity.'' It was this paper which was laughed at by the ''connoisseurs.''

Chemistry seems to have attracted Mitchell's attention to some extent, for we find him writing to Bartram in 1747 for a ''specimen of the water which turns iron to copper and the earth salts, etc., about it which I would analyze.'' There is no record, however, that he ever made this analysis.

From a letter to Bartram, dated August 1, 1750, it is apparent that he gave up his scientific studies for another form of livelihood. We find him writing about American affairs, on which, no doubt, he was an authority, based upon nearly fifty years of residence in the colony. He published a comprehensive work in two volumes, which was entitled ''The English in America.'' In this work he dwelt at length on the agricultural practices of the colonists and a description of the natural products.

At the beginning of the hostilities which preceded the French and Indian Wars, Mitchell was employed by the home government to prepare a map and a report on the condition of the colonies. ''The map which Dr. Mitchell made was issued in 1755. One hundred and seventy-one years later, in 1926, this map was twice laid before the Supreme Court of the United States of America and twice before the Law Lords of the British Privy Council. In the meantime many editions of Mitchell's map were published, many facsimiles of parts of it were made, and legal and historical arguments were repeatedly based upon its geographical features. Without serious doubt this is the most important map in American history."[29]

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[27] *Phil. Trans.*, R. S., 43: 102–150, 1744.

[28] *Ibid.*, 45: 541–563, 1748.

We now come to the most imposing and outstanding man of his time in the American colonies, namely, Benjamin Franklin, who follows next in order of election to fellowship in the Royal Society, having been elected in 1756. Franklin was born in Boston, January 17, 1706. He acquired some schooling there, but after a few years was set to work learning the printer's business, and from this time on his intellectual development was one of constant self-effort. At the age of 17 he moved to Philadelphia, where he resided and developed his many activities until his death in 1790.

Franklin was virtually the intellectual ambassador of his fellow beings at home. His remarkable services, both at home and abroad, were such that in either case his name would have made history. Also in any one of his scientific and practical attainments he contributed profoundly to the advancement of science in the colonies. During his residence in England he was extremely active in seeking privileges for his colleagues to present scientific papers before the Royal Society, securing for them memberships to academies, as well as honorary degrees from universities. He acted as agent in purchasing books and scientific instruments for the various individuals and colleges in the colonies. His associates at home were the leading scholars of the colony, namely, John Winthrop IV, of Harvard College, Ezra Stiles, of Yale College, Cadwallader Colden, of New York, James Madison, of William and Mary College, David Rittenhouse and John Bartram, of Philadelphia, as well as many others. Probably no man of his period had such a voluminous correspondence with so many of the prominent scholars on both sides of the Atlantic Ocean as did Franklin. The greater portion of this correspondence has been kept intact and is preserved in the Library of Congress.

In taking account of his contributions to science, some of Franklin's biographers enumerate them as covering twenty or more different fields of interest. It will not be possible within the limits of this paper to consider any but his major activities. It is known that he became vitally interested in science about 1743, when not quite forty years of age. However, much of his time was spent in attending to the public affairs of the colony in spite of his wish to devote his life to experimental sciences.

It was most natural that a man of Franklin's temperament would desire intellectual companionship, and this is expressed most fully in his attempt to form a society of ingenious men residing in the colonies. He knew of the success of the Royal Society of London, now over three quarters of a century in existence, and from this society he secured ideas of incorporation, membership, qualifications and other necessary details. Until this time the society had exerted great influence upon the intellectual and scientific life of the colonies. Its *Transactions* were to be found in the libraries of Harvard and Yale Colleges and in the homes of the leading scholars. The first intimation we have of the desire of Franklin to form a society is found in a circular letter dated Philadelphia, May 14, 1743, entitled "A Proposal for promoting useful knowledge among the British Plantations in America." The society was duly formed and existed for over twenty years, but in the year 1769 was merged with a rival society, and was then known as the American Philosophical Society, of which Franklin became the first president, which office he held until his death. After the signing of the Treaty of Paris in 1783 the Royal Society gradually lost influence in the colonies and its former prestige enjoyed by the American Philosophical Society.

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[29] Statement made by Dr. L. Martin, Chief, Maps Division, Library of Congress in a speech before the Am. Hist. Assoc., Dec. 30, 1927.

Much has been written regarding Franklin as an inventor, meteorologist, oceanographer, physicist, medical adviser and even as a mathematician and astronomer. However, it was through his great discoveries and contributions to electricity that he became known as a scientist. His first interest in the subject of electricity seems to have been aroused in the year 1746, when, on a visit to Boston, he attended a lecture said to have been given by a Dr. Spence, of Scotland. However, it is known that Professor Winthrop, of Harvard, was the first to give experimental lectures in electricity in the American colleges[80] (May 10, 1746) and being a close friend and correspondent of Franklin's, it is more than likely that he received his ideas from Winthrop. In 1745 Peter Collinson,[81] an English friend, sent to the Philadelphia Subscription Library with the necessary equipment a description of some electrical experiments which had been made in Germany. The following year, after his return from Boston, Franklin attempted similar experiments, and in 1747 and 1748 in a series of four letters to Collinson[82] he explains the ingenious attempts which he made to discover the properties of electrical fluid. From this time on his electrical discoveries followed in rapid succession. Franklin's first discovery was that copper or iron points had the power of drawing and throwing-off electrical matter when charged by lightning, which up to this time had not been observed by the European scientists. He also made the discovery of a plus and minus state of electrical charge, which are now known as positive and negative charges. From this principle he explained the phenomena of the Leyden jar.

He showed decisively that when the jar was charged it contained no more electricity than before, but that as much was taken from one side as was thrown on the other; and to discharge it nothing was necessary but to produce a communication between the two sides, by which the equilibrium might be restored, and that then no signs of electricity would remain. He afterwards demonstrated that the electricity did not reside in the coating, as had been supposed, but in the pores of the glass itself. After a jar was charged, he removed the coating, and found that upon applying a new coating the shock might still be received. In the year 1749, he first suggested his idea of explaining the phenomena of thunder and lightning and of the aurora borealis upon electrical principles. He points out many particulars in which lightning and electricity agree, as well as reasonings from facts, in support of his positions.

In the same year he conceived the astonishingly bold idea of ascertaining the truth of his doctrine, by actually drawing down the lightning, by means of sharp-pointed copper or iron rods, raised over buildings. Even in this uncertain state, his passion to be useful to mankind displayed itself in a powerful manner. Admitting the identity of electricity and lightning, and knowing the power of points in repelling bodies charged with electricity, and conducting imperceptibly their charge, he suggested the idea of securing houses, ships and trees from being damaged by lightning by erecting pointed rods, that should rise some feet above the elevated part, and descend some feet into the ground or the water. The effect of these, he concluded, would be either to prevent a stroke by repelling the cloud beyond the striking distance, or by drawing off the electrical charge which it contained; or, if it could not effect this, it would at least conduct the electric charge to the earth, without injury to the building.

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[80] "Phil. Exp. Lecture," .mss. note book, Treasury Room, Harvard University.

[81] James Brett, "Life of Peter Collinson."

[82] "Exp. and Obs. in Electricity made in Philadelphia." London, 1751.

It was not until the summer of 1752 that he was enabled to complete his profound discovery by experiment. The plan which he had originally proposed was to erect on some high tower or other elevated place a pointed iron rod, insulated by being fixed in a cake of resin. Electrified clouds passing over this would, according to his theory, conduct a portion of their electricity, which would be evidenced by sparks being emitted, when a key or other conductor was presented to it. Philadelphia at this time afforded no opportunity of trying this experiment. However, it occurred to Franklin that he might have more ready access to the region of clouds by means of a common kite. He prepared one by fastening two cross sticks to a silk handkerchief, which would not suffer from the rain, as would paper. To the upright stick was affixed an iron point. The string was, as usual, of hemp, except the lower end, which was of silk. Where the hempen string terminated, a key was fastened. With this apparatus he placed himself under a shed to avoid the rain and raised the kite; a thunder-cloud passed over it, but no sign of electricity appeared. He almost despaired of success, when suddenly he observed the loose fibers of his string to move towards an erect position. He now presented his knuckle to the key and received a strong spark. How great must his sensations have been at this moment! On this experiment depended the fate of his theory. If he succeeded, his name would rank high among those who had advanced science; if he failed, he must inevitably be subjected to the derisions of mankind. The anxiety with which he looked for the result of his experiment may be easily conceived. Doubts and despair had begun to prevail when the fact was ascertained in such a clear manner that even the most incredulous could no longer withhold their approval. Repeated sparks were drawn from the key, a jar was charged, a shock given and all the experiments made which are usually performed with electricity.

The far-reaching results of these experiments are only too evident in the practical developments of to-day. One specially outstanding field has developed which has been of profound importance, namely, the field of atmospheric electricity and terrestrial magnetism. Franklin's work was the direct inspiration of the very recent experiments made by two distinguished German physicists in harnessing the tremendous electrical potential of thunderstorms to a new type of x-ray tube.

The letters which he sent to Mr. Collinson, it is said, were refused a place in the *Transactions* of the Royal Society of London. However this may be, Collinson published them in a separate volume, under the title of "New Experiments and Observations on Electricity, made at Philadelphia, in America." This book went through five editions between 1751 and 1774, and has been translated into different languages.

Dr. Priestley, in his "History of Electricity," published in the year 1767, gives a full account of Franklin's experiments and discoveries. "Nothing was ever written upon the subject of electricity," he says, "which was more generally read and admired in all parts of Europe, than these letters."

The news of the brilliant discoveries of Franklin soon extended to Europe, and the world became aware of the fact that the American colonies had produced a scientist of the highest caliber, and after a hundred and eighty years the scientific world is returning at this time to the amazing generalizations made by Franklin. He was equally well qualified to construct theories as well as to perform experiments to test them. This is readily evidenced by any one of the papers on the many subjects upon which he wrote. We find eight papers published in the *Transactions* of the American Philosophical Society and eleven papers in the *Philosophical Transactions* of the Royal Society. In recognition of his many contributions to science he was honored by the Royal Society with the Copley medal in 1753 and elected fellow in 1756. In addition, he received honorary degrees from the colleges of Harvard, Yale, William and Mary and Pennsylvania. The universities of Edinburgh, Oxford and St. Andrews honored him with the degrees of doctor of laws and for his medical contributions he was elected a member of the Royal Society of Medicine, Paris, in 1776, and the Medical Society of London. At the age of eighty-four Benjamin Franklin died, the most honored man of his age, and lies buried with his wife in the Christ Church burying ground in Philadelphia.

From the study of the history and evolution of scientific thought in the colonies from 1636 until this time, we find that it has gradually been transformed to a higher level of authority, accuracy and refinement. Calvinism and Puritanism were gradually being forced to recede and become a part of the rationalism then permeating colonial life. This is embodied in the life and work of our next fellow of the Royal Society, John Winthrop, IV, who was the most profound scholar of the colony during the seventeenth and eighteenth centuries. Winthrop was the direct descendent of the Winthrops referred to earlier in this paper. We shall sketch his life briefly and analyze his contributions to early astronomy, seeking thus to justify his place in the history of science in America—as its first real scientific astronomer and Newtonian disciple. He was born in Boston, December 19, 1714, of parents already distinguished in the social and intellectual life of the community. He entered Harvard College at the early age of fourteen and immediately established his place as one of the first scholars of his class. His great fondness for mathematical studies and experimental science, combined with a temperament tending toward idealism, soon led him to contemplation of the stars and the laws governing their motions. After his graduation from college in 1732 with the degree of master of arts, he retired to his father's home and for the next six years very little was known of him. However, from two precious manuscript commonplace books now preserved at Harvard College we find evidences of private study which forecast his future work. These books reveal his wide general reading, and recorded observations of natural phenomena such as sun-spots, magnetic variations and meteors, mathematical problems and philosophical meditations. Upon the forced retirement of his own professor, Isaac Greenwood, there was a vacancy in the Hollis professorship. The overseers of the college had not far to look for a successor. John Winthrop was appointed, at the age of twenty-four years, to become full professor of mathematics and natural philosophy. He had been examined as to his proficiency in mathematics and the physical sciences, but the question of examining [illegible] religious statutes gave the authorities real concern. His views were suspected as being a little too broad for Harvard, even though his ideas embodying the spirit of the Lockean or English philosophy of empiricalism were just the force that Harvard needed. At any rate, he was accepted on the first examination and passed over on the second, and duly inaugurated to the office which he held for the next forty years with honor and distinction to Harvard and to the history of cultural progress in America. One of the most remarkable steps he took at the beginning of his professorship was to secure a copy of Newton's "Principia." At the age of twenty-five, we find Winthrop assiduously engaged in mastering the "Principia," which he so brilliantly applied to all his long years of subsequent work in astronomy and natural philosophy and in research and class instruction.

The modern laboratory was not known then, but Winthrop possessed apparatus which will illustrate the fundamental facts of natural philosophy then known. "For "Astronomy," he says, "we had before been supplied by Mr. Hollis with telescopes of different lengths, one of 24 feet; and a brass quadrant of two feet radius, carrying a telescope of greater length, which formerly belonged to the celebrated Dr. Halley. We had also the most useful instrument for dialing; and for surveying, a brass semi-circle, with plain sights, and magnetic needles. Also a curious telescope, with a complete apparatus for taking the difference of leveling. From a number of gentlemen of the province the following additions were received: a fine reflecting telescope of different power; microscopes of the several sorts now in use; Hadley quadrant, fitted in a new manner, a nice variation compass, and dipping needles with instruments for the several magnetical and electrical experiments."

From an original manuscript notebook in the library of Harvard College we find the first authentic astronomical observations made by Winthrop, dated April 19, 20, 21, 22, 1739, on sun-spots with an 8-foot telescope. There are several well-executed drawings, showing the positions, apparent movement and structure of the spots. He also made observations as to their physical character but does not enter upon any discussion as to the theory of their origin. He did recognize them, however, as an integral part of the sun and not something wholly unrelated or detached. These seem to be the first scientific observations on sun-spots in America.

The next undertaking to engage our astronomer's attention was the study of the transit of Mercury over the sun, April 27, 1740. Winthrop was fully aware of the importance of transit observations, especially those of Venus, and therefore proposed to observe these rare phenomena with well-thought-out methods. This he observed with an instrument he already possessed.

The qualitative results are probably not greatly different from our present knowledge of such transits, but it is in the methods of arriving at these results that the vast improvements have been made. Without the modern clocks, chronographs and electric circuit breaks—also firmly mounted telescopes with all the accessories—it is to be wondered that Winthrop accomplished his task at all. His results were accepted by the Royal Society and published in full in the *Transactions.*[33] Winthrop was thanked by the Royal Society and asked to continue his communications, which immediately gave him high rank and finally led to his election as a fellow. He followed his first paper with observations of the second transit of Mercury on October 25, 1743, and again a third transit on November 9, 1769. The problems in these transits which interested Winthrop were: the exact determination of longitude between Cambridge and London, the equation of time, the position of Mercury's nodes, its inclination and hourly motion, and the correctness of Newton's laws of motion.

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[33] *Phil. Trans.*, R. S., 42: 572–578, 1743.

Winthrop also established the first laboratory of experimental physics in this country in order to test the laws of gravitation of bodies on the earth. In conjunction with these experiments, he demonstrated to his students the motions of planets and comets, and illustrated the problems of eclipses, etc. Of course these lecture experiments had to do also with problems of the elements of mechanics, hydrostatics, optics, heat and the theory of light and prisms according to Newton. These experimental lectures which were given by Winthrop himself before the class were conducted much as are those in a modern laboratory—except that to-day the students perform the work themselves. The experiments were extended over a long period, beginning in 1746 and continuing to 1779. It is interesting to note that his manuscript notes are still preserved at Harvard College. It was during 1771 that Count Rumford, as a student at Harvard, attended Winthrop's lectures and thus derived his first knowledge of heat and other properties of matter. He said, "I made sufficient progress in Natural Philosophy under this excellent and happy teacher."

It has recently come to light that the first introduction into our colleges of the elements of fluxions now known as calculus was in connection with the thesis required of the students under Winthrop, beginning about 1756. This marks a definite epoch in mathematical studies which has interested students of history for some time.

The year 1755 was a memorable one to the inhabitants of New England, due to the occurrence of an earthquake of some severity. The study of this phenomenon called forth Winthrop's best endeavors and revealed at the same time a large and broad-minded scientist. As a theorist, he probably was more modern than he has been given credit for. His observations, deductions and the theory he advanced, besides the theological implications, were given in two lectures in the Holden Chapel before the students and faculty. The whole treatise shows an exceptionally comprehensive study. It is also a curious intermixture of analytical chemistry, mineralogy, geology and astronomy. However, this study virtually established Winthrop as our first seismologist. He was the first in this country to apply true inductive methods to observations of the earth-movement, and to advance the theory that the disturbances of the earth-crust were in the form of waves, and transmitted a pendulum-like motion to buildings and objects on the surface. He was the first to apply computation to the phenomena, consequently discovering the analogy between seismic motion and musical vibrations; he also discovered the principle that the quicker the motion the shorter the wave-length of the disturbance. His ideas on the nature of heat were new to the science of geology, especially those relating to the internal actions of volcanoes and earth movements. An account of this earthquake was also published in the *Philosophical Transactions*.[34]

Winthrop's next public work was two lectures upon comets, and in particular on the return of the comet (1682) better known as Halley's comet, which he was fortunate to observe, since it was the first predicted return of a comet. This lecture was also read in the chapel of Harvard College, April 11, 1759, as a part of the regular and assigned duty of the Hollis professorship. Winthrop first observed this comet on April 3, after it had passed perihelion, and, like similar celestial phenomena, had caused much anxiety and speculation as to its meaning.

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[34] *Ibid.*, 50: 1-18, 1757.

In the first lecture his introduction to the subject of comets is descriptive, showing the relation and differences between comets, fixed stars and planets. This is followed by a history of their discovery with various theories concerning their origin and nature, especially during the preceding two hundred years. He computed the orbital elements of one of the comets under observation during this period; and his work upon the geometrical demonstrations, suggested by Newton, concerning the ascent of the tails of comets, received laudable notices from the Royal Society. This paper, the original of which was in Latin, entitled "Cogitata de Cometis," was communicated to the society by Dr. Franklin.[35] It contains five problems, with dependent scholia and corollaries. In these he investigates the limits of attraction between the comets and the sun, and the laws of motion and direction by which an elastic fluid or vapor arising from the head of a comet would be governed. He also deduces the masses and densities of comets from the observed breadth of the coma in the side next to the sun. In this method, which he considers as entirely new to science, he infers that the density of the comet of 1665 was to the density of the earth as 350 to 1; and that of the comet of 1682 as 5 to 11; and suggests an analogy in this respect, between comets and planets; that the densities are greater in proportion to their nearness to the sun.

His explanation of the curved appearance of the tails of comets, which are occasionally manifested, contains this remark—"that as no incurvature or deviation from the opposition to the sun is perceived, but what may arise from the progressive motion of the head around the sun, it appears probably that comets do not revolve on their axes."

In his second discourse before the college community, April 18, 1759, he discussed the true theory of comets according to the work of Newton's "Principia," and also according to the laws formulated by Kepler, with the predictions of Halley.

Again we find him in 1761 preparing, with foresight and diligence, plans to observe two events of great astronomical importance which took place in this country—the transits of Venus, 1761 and 1769. Winthrop's keen sense of appreciation of the value of such opportunities was of vital significance in America's astronomical history. This is evident from the introduction to his first discourse in 1769 on the use of the transit of Venus.

The first astronomical expedition in this country was that in which Harvard College and the province of Massachusetts participated. That Harvard had a scholar so well trained, and disposed to undertake this scientific mission speaks well for her eminence in science at that period. The ultimate success of this work depended upon the cooperation of many astronomers. European observatories, Greenwich and Paris, sent out five different observing parties to America. In Philadelphia, the American Philosophical Society authorized David Rittenhouse and a number of prominent gentlemen to make all preparation to observe this transit also. A special act of the Massachusetts government granted the use of the province sloop to convey Winthrop and two assistants, with instruments loaned by the college, to St. John's, Newfoundland. Without giving full details of the time of contacts and measurements of the passage of Venus across the sun, it is sufficient to say that the results of the calculations gave the parallax of the sun as $8''.25$. This value is apparently not the mean value of the parallax as it was derived from one set of observations based upon Halley's method; namely, the "method of duration," that is, observation of the contacts, and also of the position of the planet on the sun. While Winthrop observed this transit very thoroughly and made careful computations, yet his instruments and methods were naturally not such as to give results to be compared with those of Newcomb and others from the transits of 1878 and 1882. However, he later gathered all available observations, and from these determinations found the sun's parallax, at its mean distance from the earth, to be 8″.68, which is comparable with the present accepted value. In the second transit of Venus (June 3, 1769), which again called forth important preparations both in Europe and the colonies, similar observations were made by Winthrop in Cambridge, by West in Providence, and by Rittenhouse in Philadelphia.

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[35] *Ibid.*, 57: 132–154, 1767.

Winthrop was the main support of Franklin in his theories and conclusions relative to his experiments in electricity. With Franklin, he was virtually the founder of the study of atmospheric electricity. He also carried on magnetic and meteorological observations of which records and computations are still preserved. Parallel to his observations on earthquakes and magnetic variations, he observed regularly the appearance of the Northern Lights from 1741 to 1757. He also made a study of the physical appearance of Venus, eclipses of Jupiter's satellites, partial solar eclipses and aberration of light.

In all, Winthrop published his scientific results in six pamphlets and contributed eleven papers to the Royal Society.

There is another outstanding fact concerned with the history of our country's intellectual progress that is not generally known—namely, that the founding of the American Academy of Arts and Sciences can be attributed to Winthrop. With a strongly intellectual community now developing in Boston, our Winthrop found great need of further expression of scientific ideas. He was a close friend of John Adams and both of them were more or less jealous of the advances that Philadelphia was making in various ways. On several occasions both gentlemen discussed the possibility of founding an academy in Boston similar to the American Philosophical Society. Winthrop's health and manifold duties did not permit an active part in this undertaking, but you will note that all the best students who graduated under him are among the incorporators of the American Academy. During the trying times of the revolution with the mother country from 1775 to 1779, our scholar was an ardent patriot and espoused the cause of the colony. He was a councillor and friend of Washington and of others who stood high in the founding of the new republic.

Winthrop was honored as no man of his time had been. He was easily recognized as the most learned and capable of men during a period of over forty years of service to Harvard College. The Royal Society elected him as a fellow in 1766 and the American Philosophical Society enrolled him as a member in 1768. From the University of Edinburgh he received the honorary degree of LL.D. and his alma mater conferred the same degree upon him in 1773—the first honorary degree of doctor of law conferred by Harvard University.

In Cambridge, on May 3, 1779, at the age of sixty-five, John Winthrop, scholar, scientist and astronomer, passed away in the fulness of his fame. He lies buried with his ancestors in the old King's Chapel burying ground, Boston.

John Morgan, founder of the first medical school in America, was born in Philadelphia, 1735, and attended the College of Philadelphia, where he received his first degree in 1757. Young Morgan followed the old custom of serving as an apprentice to a well-known physician, and later became the resident apothecary to the Pennsylvania hospital, and from there saw service as an army surgeon. Thus he laid the foundation of a notable medical career which he enjoyed until the end of his life. In 1760 we find him studying in London under the famous Hunter brothers, and later in the well-known Medical School in Edinburgh, from which many of our colonial doctors graduated. He received his M.D. degree in 1763 from Edinburgh after presenting a thesis entitled "De Puopoiesis" in which he advanced the first ideas that pus was a secretion formed by the blood vessels when in a state of inflammation.

Morgan continued his medical studies, especially in anatomy, in the medical school of Paris. Here he had the great honor of reading two papers before the Royal Academy of Surgery, the first of which was entitled "Suppuration," and the second "On the Art of Making Anatomical Preparations by Corrosion." These lectures merited him the honor of election to that society. Morgan traveled extensively in Italy, France and England, and before sailing for home was elected a fellow of the Royal Society in March, 1765, in spite of the fact that he made no scientific contributions to the society's *Transactions*. He was also a licentiate of the Royal College of Physicians and the College of Physicians of Edinburgh.

The young colonial physician, fresh from study and travel, having met the best medical scholars of Europe and having received the highest honors in recognition of his ability, returned home ready to be of inestimable service to his country. He seems to have made special effort to prepare himself for the career of a medical teacher, as he took immediate steps for the establishment of a medical school at the College of Philadelphia according to the best ideas prevalent at that time. The project met with the immediate approval of the board of trustees, and on May 3, 1765, they elected him professor of the theory and practice of medicine, and on May 30th of the same year he delivered his famous inaugural address entitled: "Discourse upon the Institution of the Medical Schools of America." In this address Morgan laid down a very comprehensive plan for the preparation and education of all students of medicine, which plan has, in the main, been upheld by all our modern medical schools connected with universities. The first two professorships established were in anatomy and materia medica. Dr. William Shippen, Jr., a fellow student of Morgan while he was in Europe, gave the lectures on anatomy and surgery, which consisted of the structure of all parts of the body, and the various diseases affecting them, as also their various cures. All the necessary operations in surgery were performed, and courses in bandaging and the practice of midwifery were given.

Dr. Morgan lectured on materia medica, which consisted of the study of medicine in general and the proper manner of conducting the study of physic. He also took up the study of the virtues of different plants and their comparative powers of curing. His lectures upon pharmaceutic chemistry were open to students of both chemistry and pharmacy, and included some critical lectures upon the chief preparations contained in the "Dispensatories" of the Royal College at London and Edinburgh.

In October, 1775, General Washington appointed Dr. Morgan medical director of the Continental Army. Morgan set to work to bring order out of the chaos which existed in the Army Medical Department and instituted rigid examinations for those desiring to enter the medical service, and also exercised the most vigilant supervision over the work of the entire department. The jealousy and insubordination of the regimental surgeons contributed to his dismissal from his post of director general. As a result of this affair Morgan issued a pamphlet entitled "A Vindication of His Public Career in the Station of Director-General of the Military Hospitals and Physician-in-Chief to the American Army." Boston, 1777. Morgan's demand for vindication was finally heeded by Congress, and a formal investigation of the charges two years later proved Morgan innocent.

Morgan contributed three papers to the *Transactions* of the American Philosophical Society, of which the following are brief abstracts.

The art of Making Anatomical Preparations.[36]

A discussion on the method of preparing models of the vascular system of anatomical specimens as first used by Dr. Nichols in London and later introduced by the author in Paris, in which the advantage of its features over the older and more cumbersome method of dissection are pointed out so as to prompt its use by students in this country.

Of a Living Snake.[37]

Statement of the case of a living horse, 9 years old, with a live snake in its eye, given as supportive evidence for the theory of spontaneous generation. Several other cases of worms and snakes found in abnormal places are also mentioned. (The author does not seem to be a strict adherent to the theory, but rather is in doubt just which is correct.)

Some Account of a Motley Colored or Pye Negro Girl.[38]

Statements of the case of a negro girl with areas of white skin diffusely scattered over all portions of her body, and the case of the mulatto boy also showing areas of white skin contrasted with the slightly deeper natural hue.

Morgan possessed an ample fortune and he spent his latter years in collecting valuable works of art and accumulating a fine library. These were partly destroyed by British during the Revolutionary War. He died on October 15, 1789, and both he and his wife are buried in St. Peter's churchyard in Philadelphia.

John Tennent was a native of England and came to the United States about 1725. Little seems to be known about his early life and education, but he was apparently a man of unusual ability. He revisited England about ten years later, and upon his return to Virginia published what appears to be the first work on medicine printed in Virginia, namely "An Essay on the Pleurisy," printed by William Parks in Williamsburg in 1736. He also wrote a treatise on the diseases of Virginia and the neighboring colonies, but apparently this was never printed. He was an exponent of the virtues of Seneca (rattlesnake root) as a specific for many diseases. Tennent found that the Seneca Indians used rattlesnake root as a remedy for snake-bite, carrying it powdered in their shot bags for immediate use. He administered it to patients ill with pleurisy, pneumonia, gout and intermittent fever. In the year 1738 and again in 1742, in Williamsburg, he published "An Epistle to Dr. Richard Mead Concerning the Epidemical Diseases of Virginia, Particularly a Pleurisy and Peripneumony wherein is Shown the Surprising Efficacy of the Seneca Rattlesnake Root . . . Demonstrating the Highest Probability That This Root Will Be of More Extensive Use Than Any Medicine in the Whole Materia Medica." In another publication he gives an account of the seasonal diseases of Virginia, describing its marshes, creeks and rivers and the state of the air calculated "to bring on a relaxation of the solids and consequently a viscidity of the blood." It must be remembered that his method of determining fever was by conjecture, as the thermometer was unknown for medical use.

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[36] *Trans.* Amer. Phil. Soc., 2: 366–383, 1786.

[37] *Ibid.*, 383–391.

[38] *Ibid.*, 392–395.

It is recorded that he was elected a fellow of the Royal Society in 1765, and also that he possessed the degree of doctor of medicine. Apparently he made no contribution to the *Transactions* of the Royal Society.

Tennent's life in his later years seems to be as obscure as his early career. He apparently was an itinerant doctor of the colony of Virginia. Where he lived and died seems not to be known.

Alexander Garden was born in Charleston, South Carolina, in 1728, and received his medical education under the supervision of the celebrated Dr. John Gregory in Edinburgh and Aberdeen universities. He returned to Charleston in 1752, and established himself in the practice of medicine. During his residence in Charleston he became greatly interested in the flora of the colony, and with his excellent training as a scientist he was able to bring to bear a profound understanding of the important relation of plants to human welfare. In 1754, due to ill health, he was compelled to take a sea voyage, and upon his arrival in New York he was offered a professorship at King's College (now Columbia University), but it is reputed that he declined the honor. He returned to Charleston, where he amassed a fortune, being greatly esteemed and extensively employed. Although he possessed a profound knowledge of mathematics, philosophy and the science of his day, it was in botany that he made his greatest contribution to colonial science. To extend his knowledge of natural history he accompanied, in 1755, the governor of South Carolina, on an expedition to the Indian country and the mountains. On this expedition he discovered a rare earth equal to that used for Worcester china, but history does not record what became of the discovery.

Garden also made studies in zoology, especially fishes and reptiles, and kept up an active correspondence with Linnaeus, to whom he sent large collections of fishes. He also sent to Linnaeus, in 1770, a specimen of the Indian Pink Root, an account of which appears in the *Essays and Observations* of the Edinburgh Philosophical Society, Vol, 2, pp. 1–7, 1756. Linnaeus's admiration for Garden and his work prompted him to give the name "Gardenia" to an "entirely new and very singular genus, the Catti Marus of Rumphius, Amboin."

Garden was the discoverer of the Congo snake,[39] and was instrumental in sending the first electrical eels to Europe. He writes to Ellis, then secretary of the Royal Society, that he had not been able to examine the reptiles thoroughly, but the structure seemed so uncommon that he thought the specimens should go to the society immediately. Regarding the description of the Congo snake, he says that these fish (eels) are from two to three feet long with the power of shortening themselves several inches. They are about ten to fourteen inches in circumference about the thickest part of the body. The head is large, broad, flat, smooth and impressed here and there with holes, as if perforated with blunt needles. The eyes are small, flat and of bluish color, and placed about three quarters of an inch back from the nostrils, and more towards the sides of the head. He goes into some detail concerning the astonishing power they have of giving a sudden and violent electrical shock to any person or number of persons joining hands and having contact with the fish. When the eel is first caught it is capable of giving a very powerful shock.

[39] *Phil. Trans.*, R. S., 65: 102–110, 1775.

Among the papers which Garden sent to Ellis, and which were read before the society, but never published in the *Transactions,* were the following:

> The Halesia first described by doctor Garden, as appears by the letter of T. Ellis, esq. F.R.S. read before the Royal Society, November 20, 1760.
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> An account of the male and female cochineal insects. In a letter to John Ellis, esq. read before the Royal Society, December 23, 1762.
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> An account of an emphibious bipes, (the mud inguana, or syren of South-Carolina) communicated in a letter to John Ellis, esq. read before the Royal Society.
>
> An account of two new tortoises communicated in a letter to John Ellis, esq. read before the Royal Society, February 23, 1775.

Garden was honored by being elected a fellow of the Royal Society in 1773, and eventually became its vice-president. In 1783 his declining health prompted him to visit England and Scotland in the hope of arresting the disease which attacked him, but he passed away peacefully in London in 1792.

James Bowdoin was born in Boston, August 7, 1726, of wealthy and influential parents. He graduated from Harvard College (1745), and at an early age of 24 came under the influence of John Winthrop and Benjamin Franklin. Bowdoin early exhibited strong scientific inclinations instead of pursuing the mercantile career which had been designed for him. This taste for scientific pursuit induced Franklin, then twenty years his senior, to communicate to him his paper on electricity. This was the beginning of a long correspondence, both scientific and political, by which these friends became united in reputation. At the very beginning of this correspondence Bowdoin appears to have availed himself of Franklin's invitation to make observations on the theory and speculation of electricity with somewhat more independence of opinion than might have been expected from the disparity of ages. One of Bowdoin's earliest letters to Franklin suggested a forcible objection to the hypothesis that the sea was the grand source of electricity, which caused Franklin a year later to withdraw his suggestions on this subject. This same letter of Bowdoin's contained an elaborate explanation of the cause of the crooked direction of lightning, which Franklin pronounced both ingenious and solid, adding "when we can account as satisfactorily for the electrification of clouds, I think that branch of natural philosophy will be nearly complete." Many of these letters which passed between Franklin and Bowdoin were read before the Royal Society, and at a later date were published in a collected form.[40]

Bowdoin's later scientific works were published in three papers, which consisted in the main of a philosophical discussion of the subject of the new theory of light as advanced by Newton. The Newtonian theory of light was known as the emission or corpuscular theory of light in opposition to the undulatory or wave theory as advanced by Huygens much earlier and which Franklin had accepted. In these papers Bowdoin, in the main, refuted the arguments of Franklin. Since the beginning of the struggle of the adherents of these theories much theoretical and experimental work has been done, and to-day each theory has shown that it possesses facts of great value and upon which the quantum theory depends.

Bowdoin begins the controversy by quoting Franklin's arguments[41] as follows:

> With respect to the hypothesis, it is asked—"May not all the phenomena of light be more conveniently solved, by supposing universal space filled with a subtle elastic fluid, which, when at rest, is not visible, but whose vibra-

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[40] Franklin, "Experiments and Observations on Electricity," London, 1751.

[41] *Memoirs,* Am. Acad. Arts and Sci., 1: 188–189, 1785.

tions affect that fine sense in the eye, as those of air do the grosser organs of the ear? We do not, in the case of sound, imagine that any sonorous particles are thrown off from a bell, for instance, and fly in straight lines to the ear: why must we believe that luminous particles leave the sun, and proceed to the eye? Some diamonds, if rubbed, shine in the dark, without losing any part of their matter. I can make an electrical spark as big as the flame of a candle, much brighter, and therefore visible further; yet this is without fuel: and I am persuaded no part of the electric fluid flies off in such case to distant places, but all goes directly, and is to be found in the place to which I destine it.—May not different degrees of the vibration of the abovementioned universal medium, occasion the appearances of different colours? I think the electric fluid is always the same; yet I find that weaker and stronger sparks differ in apparent colour: Some white, blue, purple, red;—the strongest, white; weak ones, red.''

From this Bowdoin lays down his thesis in three interesting statements of which the first is as follows:[42]

I. ''Observations upon an Hypothesis for solving the Phenomena of Light: with incidental Observations, tending to shew the Heterogeneousness of Light, and of the electric Fluid, by their Intermixture, or Union with each other.''

By Franklin's hypothesis, Bowdoin reasons that if universal space be a vacuum and filled with subtle elastic fluid which is at rest, accordingly there will be complete darkness. Should, however, any part of the fluid (now known as ether) be in motion, due to vibration, and consequently the whole, we would have universal light, which in either case is not possible. Bowdoin reasons again that, even if light and sound waves were similar, then according to the theory of universal fluid light would surround objects just as sound does, but this can not be the case from the evidence shown by objects casting shadows.

In Bowdoin's second paper,[43] was: ''Observations on Light, and the Waste of Matter in the Sun and fixt Stars, occasioned by the constant Efflux of Light from them: with a Conjecture, proposed by Way of Query, and suggesting a Mean; by which their several Systems might be preserved from the Disorder and final Ruin, to which they seem liable by that Waste of Matter, and by the Law of Gravitation.''

In this paper Bowdoin proceeds to show the fallacy of Franklin's argument that according to the Newtonian theory the particles of matter called light being continually driven off from the sun's surface as well as the planets and comets would have a tremendous motion and a force exceeding that of a 24-pounder discharged from a cannon. Also that the sun and planets must be exceedingly diminished by such a waste of matter. He reasons that ''If, then, we can suppose the quantity of matter in a particle of light to be, not indeed absolutely, but comparatively, 0, its momentum will also be comparatively 0; and it can have, in that case, no visible effect on the smallest particle of dust to remove it.''[44]

The third memoir[45] sums up all Bowdoin's philosophical speculation of the universe and his comprehension of Newton's law of gravitation. It is the longest of his memoirs and apparently his final effort to advance creative philosophical thought in the colonies. He offers it in the form of ''Observations tending to prove, by Phenomena and Scripture, the Existence of an Orb, which surrounds the whole visible material System; and which may be necessary to preserve it from the Ruin, to which, without such a Counterbalance, it seems liable by that universal Principle of Matter, Gravitation.'' In this paper he argues the various hypotheses concerning the nature of the Milky Way and nebulae, and the universal aspect of Newton's law of gravitation. The paper is also characteristic of scholars of the day, in that his scientific deductions are full of theological inferences.

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[42] *Ibid.*, 1: 187, 1785.

[43] *Ibid.*, 1: 195–207, 1785.

[44] *Ibid.*, 197, 1785.

[45] *Ibid.*, 208–233, 1785.

Bowdoin's life was very similar to that of Franklin's in that they both played leading parts in the political life of their community and were strongly in favor of united colonies. Likewise, both longed for scholastic retirements. Bowdoin became governor of the Commonwealth of Massachusetts and distinguished himself by his firmness and integrity. He was also a counsellor of both Washington and Adams, and a fellow of Harvard College, one of the founders and the first president of the American Academy of Arts and Sciences of Boston, 1780. He was honored by his alma mater and the Edinburgh University with the honorary degree of LL.D. and was elected fellow of the Royal Society in 1788. The lives of Franklin and Bowdoin ran parallel even until the end, for he followed Franklin to the grave within a few months, dying on the 6th of November, 1790, and was buried in the Granary burying ground in Boston.

No more interesting or remarkable creative genius has thus far been revealed in our history than that which was embodied in David Rittenhouse.[46] A son of the soil, he was a self-made astronomer, a true product of American genius and toil and the highest embodiment of the pioneer spirit in science during the colonial period. He was born on April 8, 1732, the year of Washington's birth, near Germantown, Pennsylvania. His father abandoned paper-making, which was established in this country by his ancestors in 1690, and moved to a farm in Norriton, about twenty miles from Philadelphia. David, the oldest son, third child in a family of ten, at an early age was destined for farm work. His mechanical ability attracted attention by his boyhood productions, including a miniature waterwheel. This talent received encouragement at twelve, when he inherited a chest of carpenter's tools and mathematical books from his maternal uncle. No schooling beyond the three R's was available, but he assimilated all the books he could procure showing special fondness for mathematics and astronomy and covering plow-handles, fences, stones and barn doors with figures and constellations. At seventeen he made a wooden clock, followed by a metallic timekeeper. His father reluctantly let him quit the plow, and at nineteen he opened a shop on the farm for clock-making, where he worked and studied assiduously, seriously impairing his health. At this time he is said to have mastered Newton's "Principia" in the English translation of Mr. Mott; and with his native ability, he laid the broad foundation for his future astronomical work. Among his great mechanical contributions to the history of instrument-making in this country was his construction of a transit instrument, the first made in America. This is still preserved in the venerable American Philosophical Society in Philadelphia. Aside from constructing a number of astronomical clocks, of which one is also preserved in the rooms of the above society, he made the first orrery in America in 1767.[47] One, the first, was made for the College of New Jersey and the second for the University of Pennsylvania, which is still to be seen there. The technical skill and the profound knowledge of astronomy was most essential in carrying out these mechanical devices.

Rittenhouse's first astronomical work was the complete study of the transit of Venus,[48] which included the work of others. A projection of this transit was laid before the American Philosophical Society. The society appointed three committees and selected three observing sites. The first was State House or Independence Square in Philadelphia, the second on the farm of Rittenhouse some twenty miles northwest of Philadelphia, and the third near Cape Henlopen. Each of these were in the charge of prominent scholars of the community. The society lacked funds, and instruments were expensive. Politics helped to equip the State House station. It was "provided with an excellent sector of 6 feet radius, made by the accurate Mr. Bird, and an equal altitude and transit instrument, both belonging to the honourable Proprietaries of this province, which the Governor very generously lent to the society on this occasion." Telescopes and additional equipment for the State House Square were obtained from England. The farm did not fare as well. A Gregorian reflector with a Dolland micrometer was ordered from London to be used by Dr. Smith. With it came lenses for a refracting telescope for Harvard. Arriving too late to be forwarded before the great event, they were impressed into service, fitted together by Rittenhouse and used by Mr. Lukens.

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[46] Portion of this sketch was furnished by Dr. W. Carl Rufus.

[47] *Trans.*, Am. Phil. Soc., 1: 1–3, 1789.

[48] *Ibid.*, 1: 4, 8–38, 1789.

Rittenhouse was left to his own resources. In preparation he made an equal altitude instrument, a transit telescope and an excellent timepiece, upon which depended the accuracy of the observations. He spent several months determining the latitude and longitude of the observatory, rating the clocks and making preliminary computations.

The success of the observations was due to Rittenhouse. Maskelyne, the astronomer royal of England, acknowledging their receipt from the Honorable Thomas Penn, governor of the province, says, "I thank you for the account of the Pennsylvania observations, which seem excellent and complete, and do honor to the gentlemen who made them." Rittenhouse immediately began the reductions. Data by the Norriton station combined with Greenwich observations gave the most accurate value of the sun's distance, 92,940,000 miles, in striking agreement with the present adopted value, 92,900,000 miles.

Rittenhouse also observed an atmosphere of Venus, a phenomenon which escaped the astronomer royal. Other astronomical activity of Rittenhouse during this period included a transit of Mercury, November 9, 1769, a survey between the observatories of Norriton and Philadelphia, observations of Lexell's comet, 1770, and the determination of its orbit, "the fruit of three or four days labor." A paper on "An Easy Method of Deducing the Time of the Sun's Passing the Meridian" attracted the favorable attention of VonZach.

Early in November in 1768 Rittenhouse[49] began building the Norriton Observatory, the first astronomical observatory in the colony. This was to be equipped with the above-mentioned instruments, but due to labor trouble and weather conditions, and possibly the "ill state" of his health, apparently the observatory was never completed, and had his project been fully realized no doubt this observatory would have paralleled any in Europe at that date. However, despite its incompleted state, Rittenhouse accomplished his great objective, namely, to observe the transit of Venus.

Rittenhouse contributed nineteen papers in all to the *Transactions* of the American Philosophical Society, and therefore it is not possible, within the limits of this paper to review them all. It is, however, important to call attention to our self-disciplined scholar's great aptitude to higher mathematics, in which field he attained some degree of

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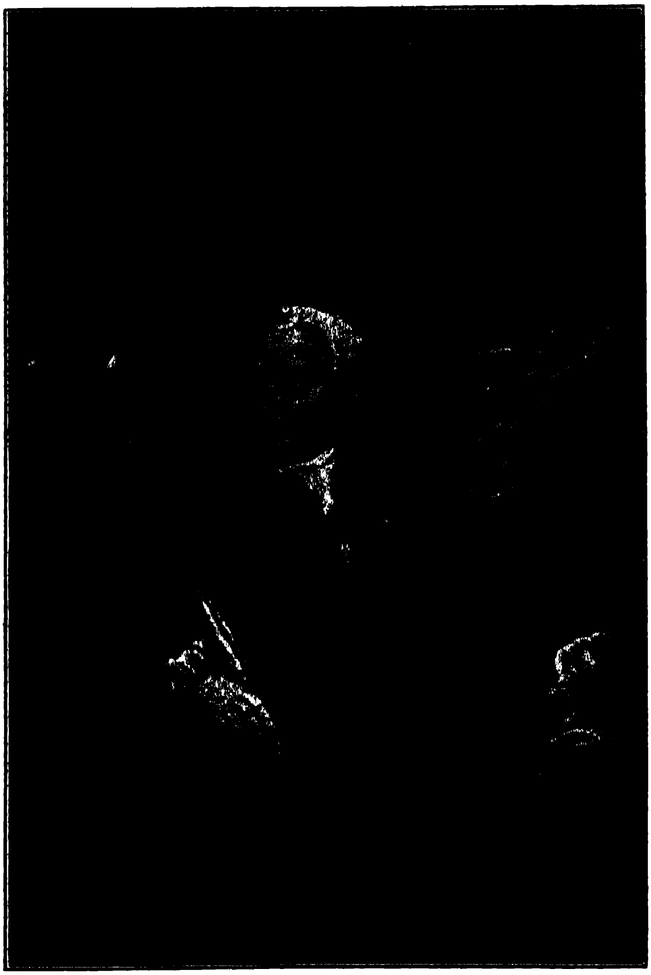
[49] *Ibid.*, 1: 8–12, 1789.



BENJAMIN FRANKLIN

FROM AN OLD ENGRAVING BY FISHER FROM THE MASON CHAMBERLIN PORTRAIT.

success. Rittenhouse writes, in May, 1792, to his friend Robert Patterson, professor of mathematics at the College of Pennsylvania, "to discover if any one has been able to determine a method of finding the sum of the several powers of the sines, either to a radius of unity or any other."[50] His problem is:

> The sums of the odd powers of the sines bear a very simple relation to each other, and so do the sums of the even powers. But all the sums of the odd powers are incommensurable to all those of the even powers.
>
> If we take the radius equal to unity, the sum of all the sines, or their first powers, will be = 1, and the sum of all their squares = 1/2 multiplied by the arch of 90°. The sum of all their cubes is = 2/3, and the sum of their fourth powers = 3/8, multiplied by the arch of 90°. The sum of the fifth powers is = 8/15, and the sum of the 6th powers = 5/16 multiplied by the arch of 90°.

Rittenhouse was able to demonstrate the first two cases by ordinary arithmetical means, but the others were investigated by the method of infinite series. The subject of infinite series was just being revived by the leading

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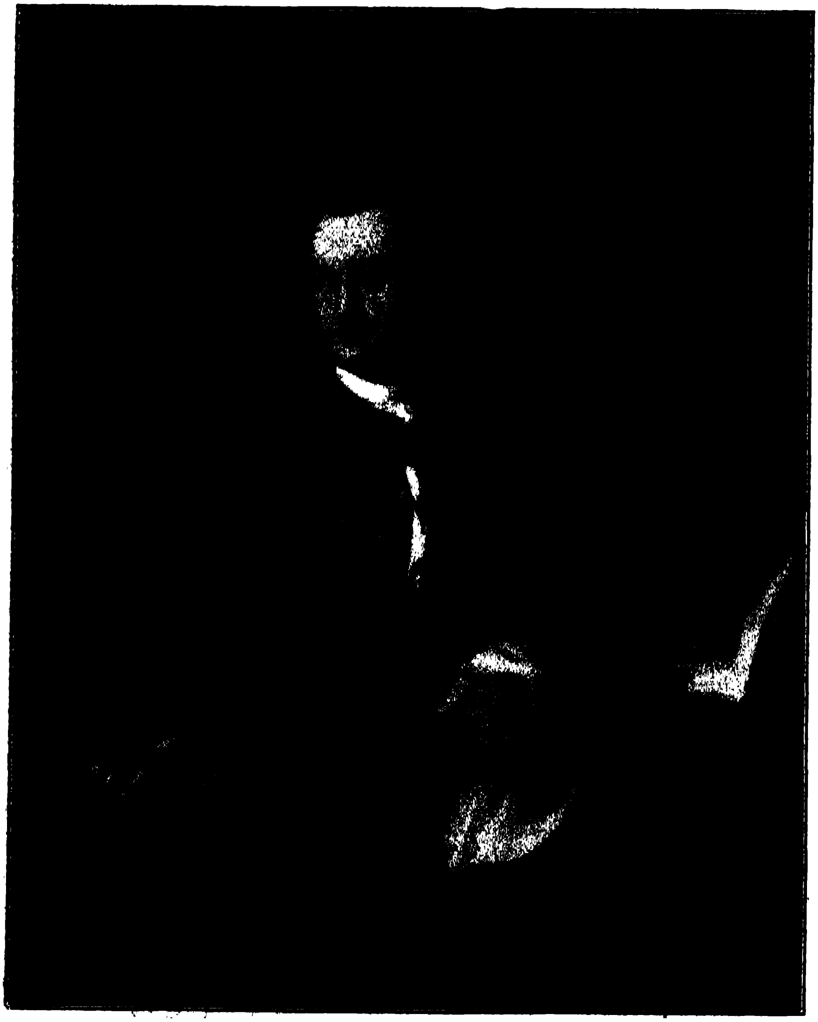
[50] *Ibid.*, 3: 155–156, 1793.



DR. JOHN MORGAN
REPRODUCED FROM MORRIS'S "EARLY HISTORY OF MEDICINE IN PHILADELPHIA."

scholars of Europe and to Rittenhouse credit must be given for keeping abreast of his time. His next paper,[51] of interest in the history of mathematics in the United States was a "Method of raising the common Logarithm to any number immediately." Here he demonstrated by laborious calculations the results which we to-day attain within a few minutes by the use of the modern slide rule.

The third mathematical paper[52] of Rittenhouse is upon the use of converging series to determine the true place of a planet in an elliptical orbit directly from the mean anomaly. For simplicity of method there is little to be desired in his manner of attacking the problem. This paper further reveals his venture into the realm of higher mathematics, especially into celestial mechanics without the use of modern calcu-

[51] *Ibid.*, 4: 69-71, 1799.

[52] *Ibid.*, 4: 21-26, 1799.

lus. From a study of these three particular problems and his method of analysis it is evident that Rittenhouse arrived at some notion of fluxion which he is reputed to have discovered for himself independently of Newton.

On February 24, 1775, Rittenhouse delivered an historical oration[53] before the American Philosophical Society, in which address he considered the whole of the history of astronomy, pointed out some of the impending problems and the cultural effect upon the human mind. Like his senior contemporary, John Winthrop, at Harvard College, he showed great breadth of mind in that he had a full grasp of the history and problems of natural philosophy, including astronomy. Likewise, the great veneration and admiration of these two men for the life and works of Sir Isaac Newton was of a common order, and demonstrated their keenness to keep in touch with the great European scientists.

The subject of the theory of light, magnetism and electricity, and allied problems, was constantly before Rittenhouse, and led to frequent discussions with Benjamin Franklin and many other local contemporaries. It is interesting to note that from the absence of correspondence it is apparent that Rittenhouse corresponded in a scientific way with no one outside of Philadelphia.

Rittenhouse enjoyed the immediate friendship of Washington, Jefferson and many others prominent in colonial public affairs. Washington appointed him the first director of the United States Mint, and upon the death of Franklin in 1790, he became the second president of the American Philosophical Society. In spite of his struggle against ill health and financial worries, his life was that of a pure idealist. This motive, combined with the will to do, carried him to the highest office any scholar could desire. Although he made no contributions to the *Transactions* of the Royal Society, Rittenhouse was elected a fellow in 1795 (the last to be elected fellow during the eighteenth century). He received honorary degrees from Harvard, Princeton and Pennsylvania colleges. He died on June 26, 1796, while still president of the American Philosophical Society, and lies buried in the Presbyterian churchyard in Philadelphia.

CONCLUSION

We have attempted in the foregoing pages to review in a very brief manner the most important contributions of the colonial scholars to the pioneer movement in the history of scientific thought in this country, as well as the extent of the Royal Society's influence during the first 150 years. Unfortunately we could not take into consideration the work of others equally important, due to the limitations imposed upon this paper, namely, that only fellows known and reputed to have been elected to the Royal Society were to be considered. It seems rather incomprehensible that the names of John Clayton (1693–1773), of Virginia, in botany; John Bartram (1699–1777), of Philadelphia, in botany; Cadwallader Colden (1688–1776), of New York, in electricity and gravitation; and Thomas Robie (1689–1729), of Harvard College, in astronomy and mathematics, besides various well-known tutors of Harvard and Yale Colleges, did not appear on the records of the Royal Society as fellows. This strange omission, however, does not in any way detract from their importance as scientists, and their work will be considered when a fuller history of colonial science is written. We also regret that it is not possible to consider the works of Benjamin Thompson (Count Rumford), elected fellow in 1779 and Joseph Priestley, fellow, 1776,

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[53] Barton, "Memoires, on the Life of David Rittenhouse," Philadelphia, 1813.

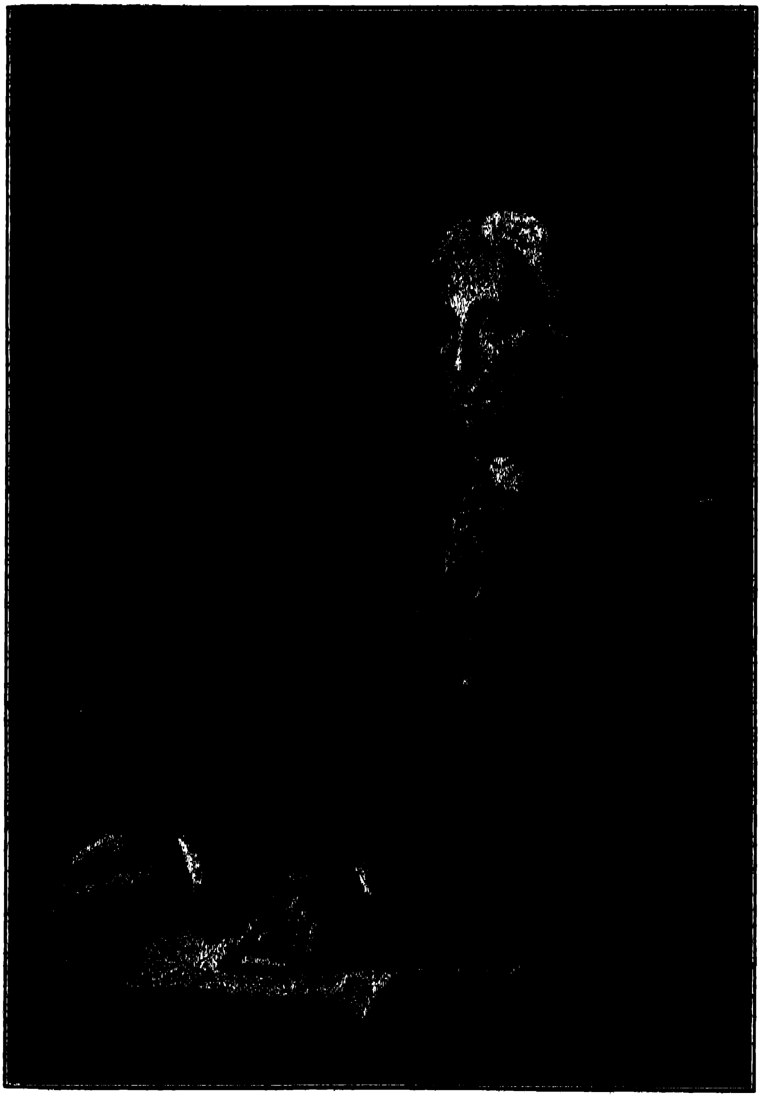
JOHN WINTHROP

ENGRAVED FOR THE COLONIAL SOCIETY OF MASSACHUSETTS FROM A PORTRAIT BY COPLEY IN POSSESSION OF HARVARD UNIVERSITY.

as the interchange of their abode was such that each made their greatest contributions to science while not residents of the colonies.

In closing this brief survey of the transition and progress of scientific thought from the mother country to the colonies, we have attempted to show how it was dominated in part by Puritanism, natural theology and supernaturalism, which held sway until the close of the Revolutionary War, when the English school of philosophy of rationalism and empiricism in matters of science was fully attained.

The transition of civilization as carried on by the French, Spanish and Dutch during the colonization period of America in the seventeenth century seems not to have touched the British colony. This may be accounted for in the constant warfare for supremacy, or possibly because their cultural and material influence was too foreign for the

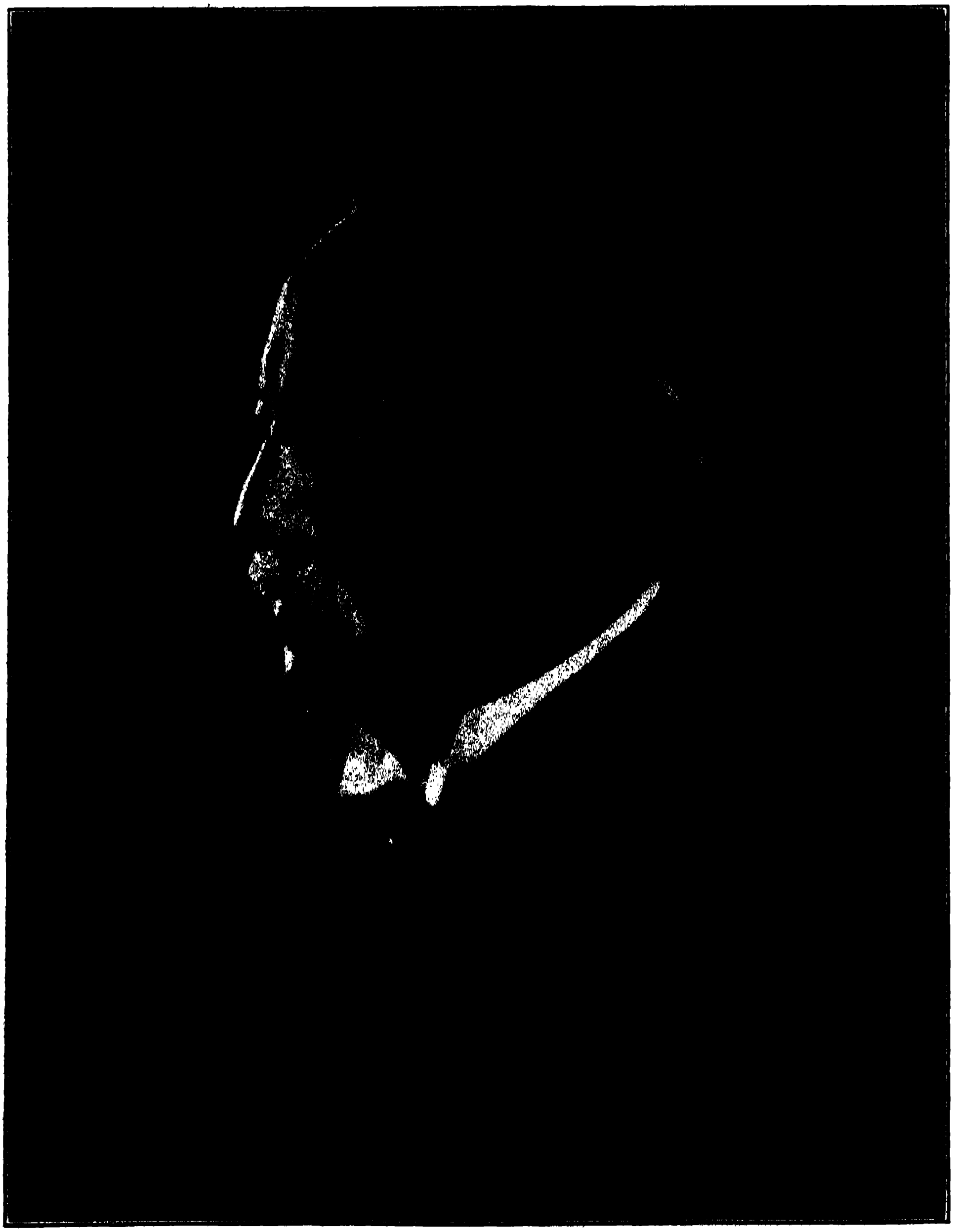


C. W. Peale, pinxit *C. Golbrecht, sculptor*

DAVID RITTENHOUSE, LL.D., F.R.S.

PRESIDENT OF THE AMERICAN PHILOSOPHICAL SOCIETY.

Puritan colonials. However, with the signing of the Treaty of Paris in 1783 there appeared a new cultural movement when French scientific thought began to play a part in the history of scientific progress in the new republic, which movement covered a period of nearly fifty years, and this in turn was followed by a Germanic influence. The history of these latter movements will form a second chapter in the history of science in the United States.

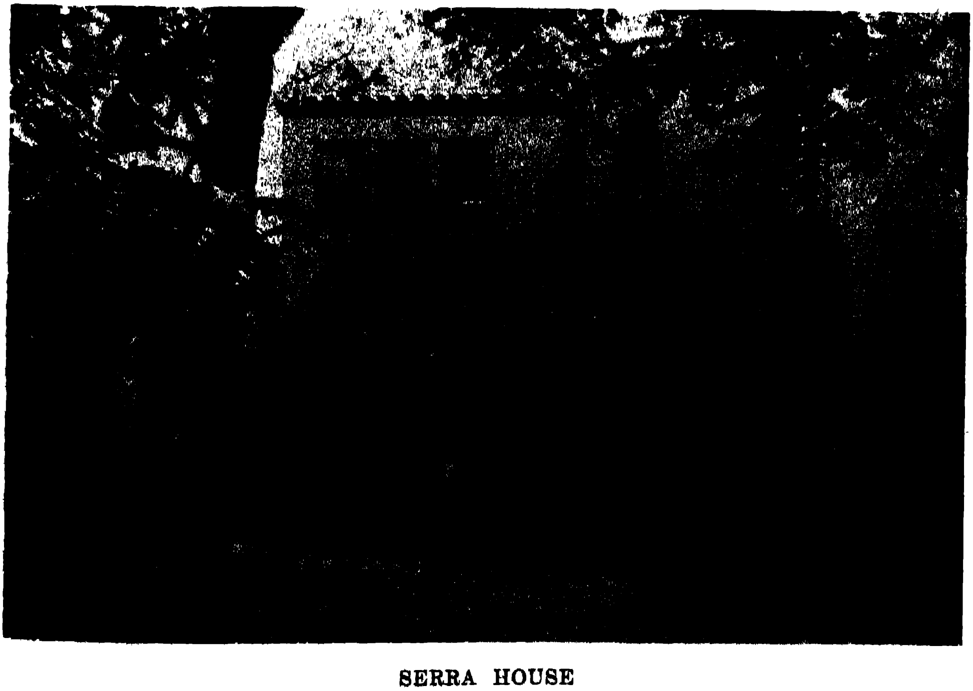


David Starr Jordan

THE PROGRESS OF SCIENCE

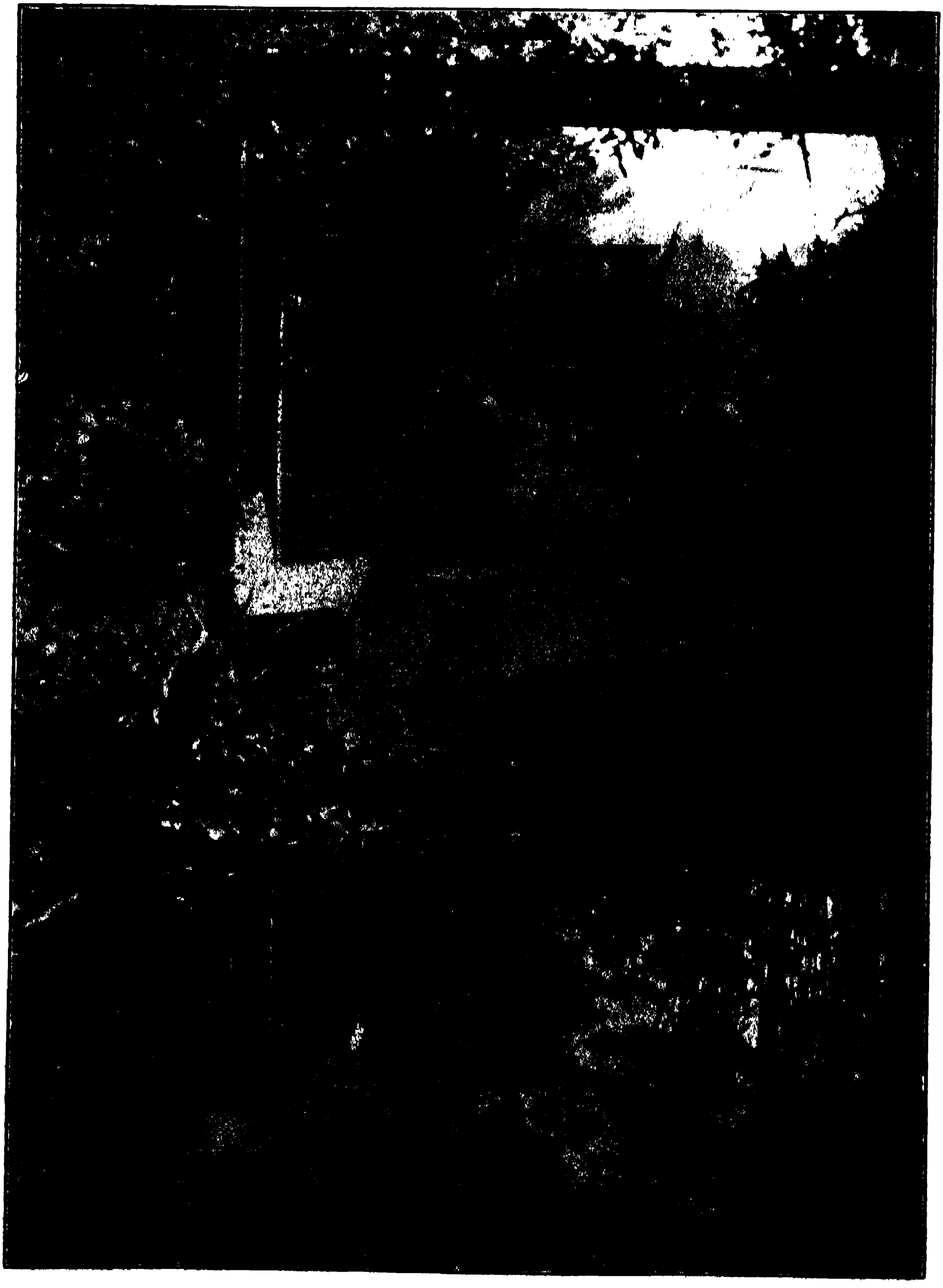
DAVID STARR JORDAN

By a fortunate chance the forces back of heredity combined to endow David Starr Jordan with a great vigorous body, an eager mind with a poetical turn, and a rare capacity to note and remember form, size and color. Men like to use their strongest powers. It was natural that a man with a love of nature who could remember every detail of structure without visible effort should be a morphological zoologist, and just as natural that when his attention was turned to fishes that he should become the outstanding systematic ichthyologist of his time. Fish are ubiquitous and of infinite variety. The free course of stream, lake and ocean give them wide range. Following them over the world was the great sport of Dr. Jordan. It led him to know many countries and men of all nations and to be a true citizen of the world. Kind, idealistic and sympathetic, the woes of others became his woes. From boyhood he had recoiled from brutality and from that highest of brutalities that is called war. As he learned more of the world and its history, war became to him the one major disease of society. To hold it in check, to fight its ravages, to work for its eradication, became his master passion. Trained as a scientist, gifted as a simple, effective, convincing speaker and author, motivated by deep feeling and conviction, he began to use his facile epigrams, his poetic powers, his writing instinct and the facts gathered by a driving personal industry to marshal the forces of peace. His ease in friendship, his willingness to travel, his capacity not to see obstacles, made him a world figure in the struggle for the



SERRA HOUSE

THE ENTRANCE TO THE JORDAN RESIDENCE ON THE CAMPUS OF STANFORD UNIVERSITY.



THE GARDEN BEHIND THE JORDAN HOME

WHERE DR. JORDAN SPENT MUCH OF THE TIME IN THE LAST YEARS OF HIS LIFE.

pacific settlement of international disputes.

It was as a teacher and university administrator that Dr. Jordan built his own memorial. Senator and Mrs. Stanford had the funds, and the general plan of founding a university, but Dr. Jordan gave Stanford University its life and purpose. Keen in his judgment of men, tolerant of the ideas of others, daring in experiment, he struck out for the best in men and in ideas and pioneered the young institution through prosperity, financial collapse, earthquake and many deferred hopes.

New thoughts and new plans intrigued him, so that his best life's work was done in the moulding of a new university. His love of man, his leadership, his own wholesome life and character, made him a towering figure in education in California and the nation.

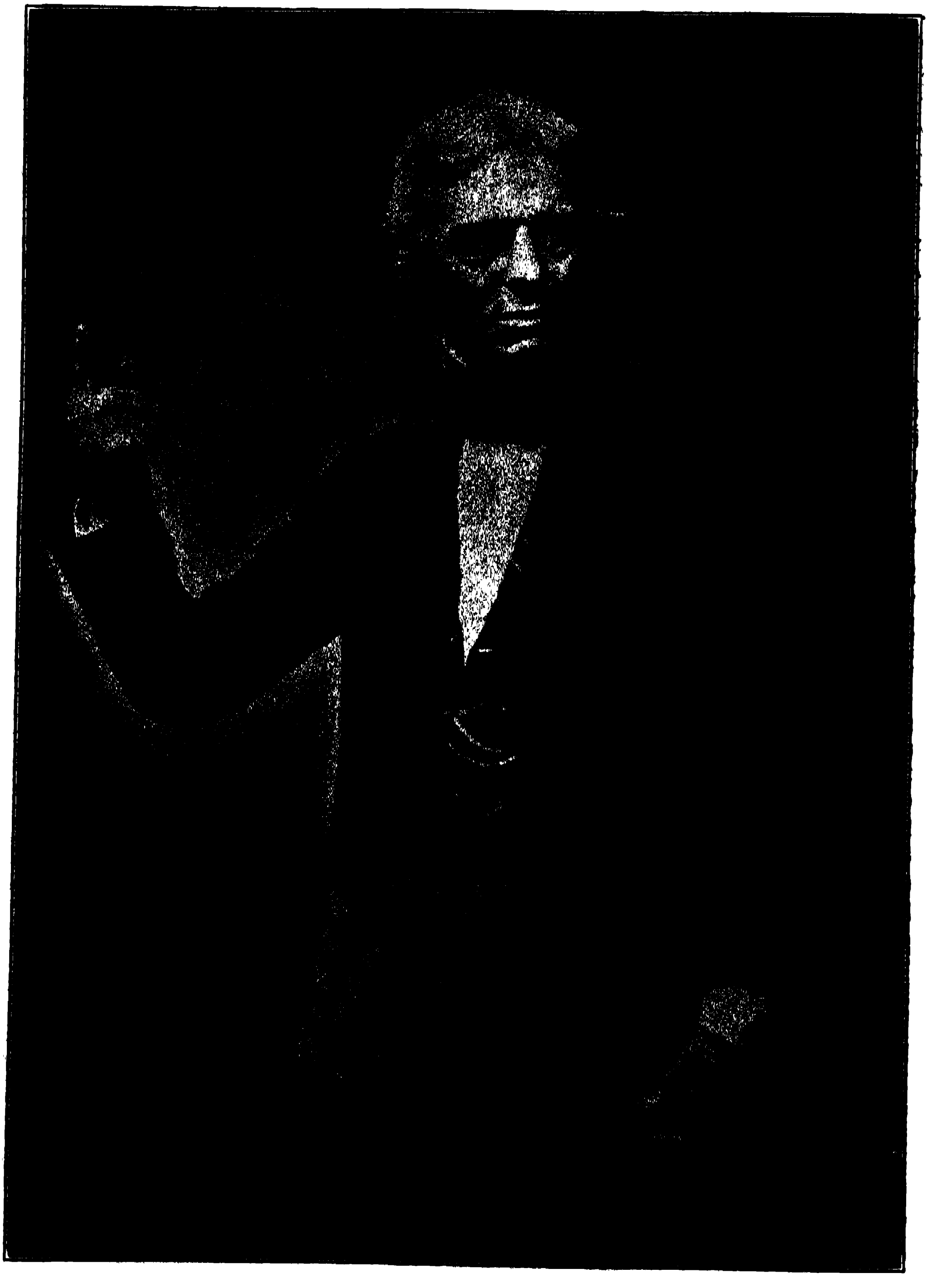
As scientist, internationalist and administrator, he thoroughly enjoyed life and gave inspiration to others. His unusual physical endowment carried him clear and unafraid into his eightieth year, when nature slowly brought him down, just as a great old oak falls in the forest. But he will live on and on in science, in literature and in the hearts of many thousands who loved him.

RAY LYMAN WILBUR

THE WORK OF FARADAY AND HENRY

FARADAY and Henry started the race toward immortality at scratch. One was New York Scotch and the other was plain English. Both had the advantage of starting poor and being self-supporting from early youth.

Faraday was eight when Henry was born. At thirteen he was apprenticed to a bookseller and bookbinder, where he remained for eight years. There he read Mrs. Marcet's "Conversations on Chemistry" and electricity in the "Encyclopaedia." One of the customers of the shop found him reading chemistry, and he was so greatly impressed by his conversation on that subject that he invited him to Sir Humphry Davy's last course of lectures at the Royal Institution. Faraday bound his notes together with illuminating illustrations and sent the copy to Davy, the director, begging him for an opportunity to quit trade, which he detested, and to take up science, which he loved. Not long thereafter, to his surprise, he obtained the coveted position as laboratory assistant. From 1813 to 1867 he both lived and worked at the Royal Institution. He married at thirty. The early years were taken up in routine and learning. In 1820 he published on two new compounds of iodine, carbon and hydrogen. The next year he made a wire carrying a current revolve around a magnetic pole. Then he became a pioneer in making alloys of steel. In 1823 he liquefied chlorine, and within the next three years he published on new compounds of carbon, and hydrogen and sulphonaphthalic acid. This work formed the basis of the dye industry. He swerved incessantly from chemistry into physics. In 1826 he was studying the limits of vaporization. From '25 to '29 he was on a committee to improve optical glass. In '29 he gave the Bakerian Lecture, "On the Manufacture of Glass for Optical Purposes." The glass was of little commercial value, but by doing the work he was enabled to get a valued assistant who remained with him for forty years. In 1831 he published papers on "A Peculiar class of Optical Deceptions" and on "Vibrating Surfaces." He was now forty years old and destined to begin and bring to quick fruition within the year the experiments on the production of electricity from magnetism. This is basic to the electrical industry. Quite properly the world joined with the Royal In-



MICHAEL FARADAY

stitution this September for centennial celebration.

Tyndall said Faraday's method of attack was intuitive rather than logical. Oersted (1820) had discovered that magnetism may be produced by electricity. Faraday inferred therefore that it should be possible to produce electricity from magnetism. Before we discuss his approach to this thesis, suppose we go back and see what has happened to his competitor in the meantime.

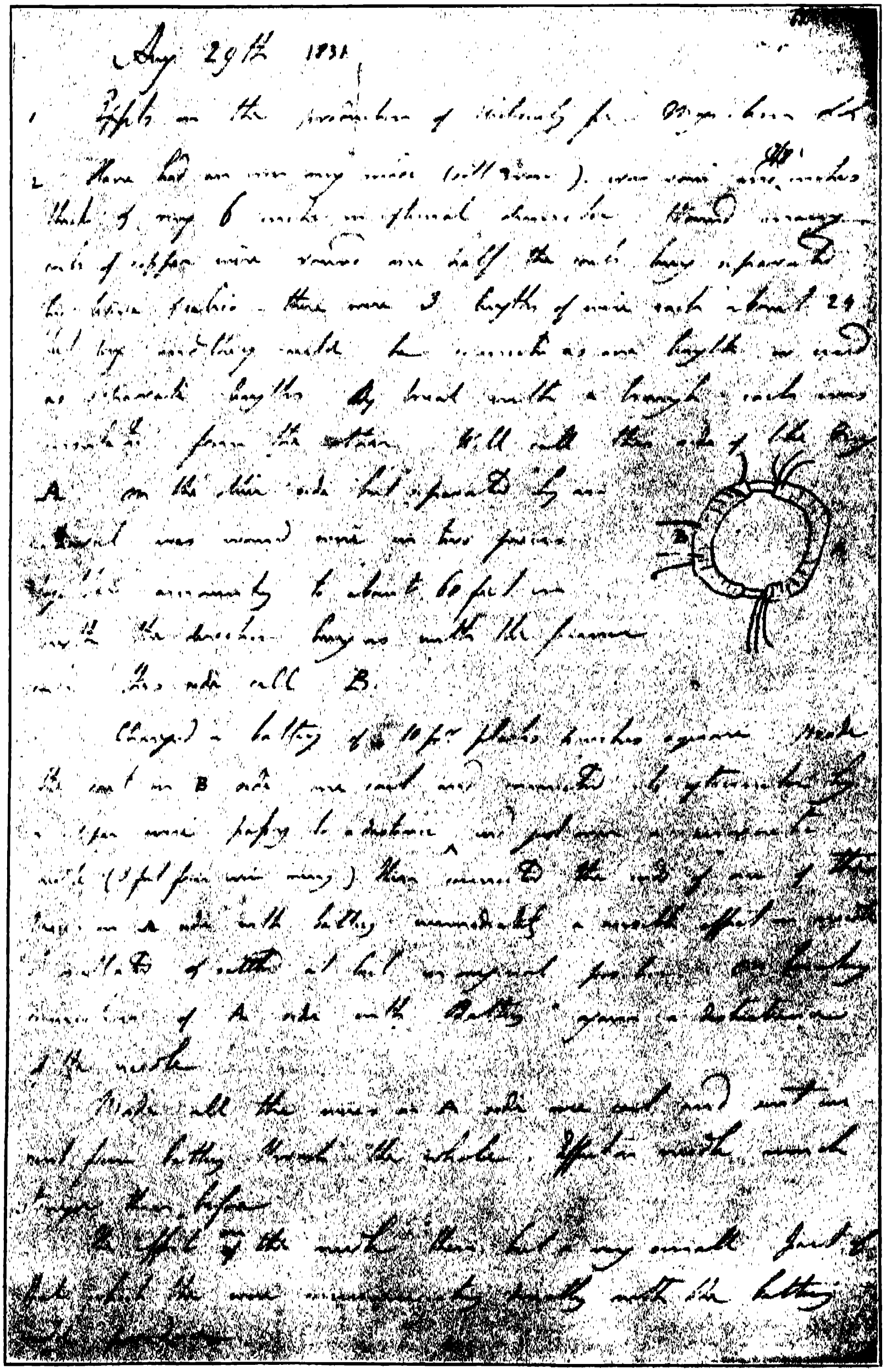
Joseph Henry had no more schooling than Faraday. His mind also was inquisitive, but he had less aptitude for study. His father died when he was nine and he was truly a child of fortune. Once he was chasing a pet rabbit through a foundation wall and discovered a back entrance to the bookshelves of the village library. There he found a book—"Brooks Fool of Quality." He returned several times to finish the book and finally read all the fiction available. Like Faraday he was an office boy in a store and later at fifteen he became an apprentice to a silversmith. There he learned to use his hands. When the store failed he had free time to gain a fondness for the theater. He joined a juvenile theater society, dramatized a tale, wrote a comedy, took part in the presentation and quickly became the president.

While ill at his mother's home he picked up a book left by a boarder, "Lectures on Experimental Philosophy, Astronomy and Chemistry intended chiefly for young persons. By G. Gregory." It is interesting that a chance book should have been the key to his career as it was with Faraday. On the fly leaf of this book he wrote, "This book although by no means a profound work has, under Providence, executed a remarkable influence on my life." "It accidentally fell into my hands—It opened up a new world of thought and enjoyment, invested things before almost unnoticed with the highest interest: fixed my mind on the study of nature, and caused me to resolve to immediately commence to devote my life to the acquisition of knowledge." As soon as he was able to attend the Theater Society he resigned from the presidency and announced that he would henceforth play his part on another stage.

He went to night school at the Albany (N. Y.) Academy and taught country school in the daytime. Later, he tutored the sons of General Van Rensselaer—and following this directed a road survey. Then at the age of twenty-seven he was made an assistant at the Albany Academy and in 1828 was promoted to professor of mathematics. It seems miraculous that such a young man, without education, experience or contact with any other research man, should do most profound research work immediately. Moreover, he lived in a community that had not deified science since the time of Franklin. He progressed more by that kind of thinking used by the Yankee inventor than by the use of lengthy logic. Yet he did not seem to have the least desire to invent for riches.

Sturgeon had made the first practical electromagnet by bending a piece of steel in U shape and winding 18 turns of copper wire around it. The steel was covered with insulator. Henry reasoned that more turns would make a stronger magnet. So he conceived the idea of covering the wire with silk insulation instead of insulating the iron core. This permitted 400 turns instead of 18. But it was hard work to put so many turns directly on a horseshoe magnet, so he devised the method of winding the wire on a "spool" or "bobbin" and then slipping the spools over the magnet. If the wheel is man's greatest mechanical invention then we must give a high place in the electrical field to the invention of the bobbin.

Henry in 1829 found that two of these bobbins or coils, connected to separate batteries, increased the lift of his magnet



Aug 29th 1831

1 Expts on the production of Electricity from Magnetism &c

2 Have had an iron ring made (soft iron), iron round and 7/8 inches thick & ring 6 inches in external diameter. Wound many coils of copper wire round one half the coils being separated by twine & calico — there were 3 lengths of wire each about 24 feet long and they could be connected as one length or used as separate lengths. By trial with a trough each was insulated from the other. Will call this side of the ring A. On the other side but separated by an interval was wound wire in two pieces together amounting to about 60 feet in length the direction being as with the former coils. This side call B.

Charged a battery of 10 pr. plates 4 inches square. Made the coil on B side one coil and connected its extremities by a copper wire passing to a distance and just over a magnetic needle (3 feet from iron ring). Then connected the ends of one of the pieces on A side with battery; immediately a sensible effect on needle. It oscillated & settled at last in original position. On breaking connection of A side with Battery again a disturbance of the needle.

Made all the wires on A side one coil and sent current from battery through the whole. Effect on needle much stronger than before.

The effect on the needle then but a very small part of that which the wire communicating directly with the battery

A PAGE OF FARADAY'S DIARY

RECORDING THE DISCOVERY OF ELECTROMAGNETIC INDUCTION.

from 14 to 28 pounds, whereas if the two coils were connected end to end to the same battery the lift was not increased. On the other hand, he found that if the magnet was operated with a long external circuit the greater lifting force was obtained by placing the coils in series. Thus connected and with 1,060 feet of copper wire in external circuit, the magnet would support a half pound weight. He remarked that this looked as though the telegraph might be possible. He created this type of magnet, which he termed "Intensity Magnet." Also in 1831 he placed the coils in parallel where there was no external resistance and succeeded in lifting a 2,300 pound weight with an 82½ pound magnet. This was his quantity type magnet.

About the same time he made a demonstration of the telegraph. A mile of wire connected a battery and an intensity magnet. A narrow steel rod as a permanent magnet was pivoted to swing horizontally like a compass needle. One end was near the soft iron core of the magnet, and the opposite end was near a small stationary office bell. At each excitation of the electromagnet, the free end of the compass rod tapped the bell. The professor repeated this exhibit before his classes in 1831 and 1832, and he continued to make this demonstration after going to Princeton. Also he extended a circuit across the campus from his house to the laboratory, so that he might communicate relative to the serving of his meals. These illustrate his usual approach to knowledge.

In July, 1831, an account appears in *Silliman's Journal of Science* of the first electric motor. He wrote to the editor:

> I have lately succeeded in producing motion in a little machine by a power which I believe has never before been applied in mechanisms—by magnetic attraction and repulsion. Not much importance, however, is attached to the invention since the article in its present state can only be considered a philosophical toy; although in the progress of discovery and invention it is not impossible that the same principle or some modification of it on a more extended scale may hereafter be applied to some useful purpose. But without reference to its practical utility and only viewed as a new effect produced by one on the most ingenious agents of nature, you will not think it unworthy of a place in the *Journal of Science*.

In this motor a straight armature was wound with wires and pivoted above a horseshoe magnet. Either end down made contact with a separate battery so that there was continuous rocking motion. The modern motor disposes of the reciprocating motion by using the commutator.

Prior to September, 1831, Henry had made several experiments on the self-induction of an electric current. When a simple coil of insulated copper strip was disconnected from the battery circuit, he noted a fatter spark than when the coil was not interposed. He used the human body to measure the "projectile force" or "intensity" of this induced current. The body was a voltmeter. With low resistance circuits the galvanometer sufficed. When two closed coils were side by side, the stopping of the current in the first coil would induce

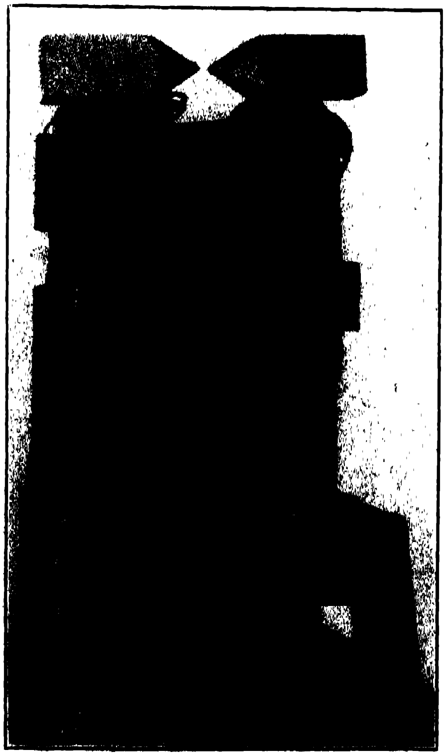
FARADAY'S "GREAT' ELECTROMAGNET

JOSEPH HENRY

a current in the second. This discovery of mutual inductance is the basis of much of our electrical machinery to-day. Henry further showed the principle of changing voltage and current as applied to transformers. It is now generally agreed that Henry was an independent discoverer of electromagnetic induction, but standard practice gives credit to Faraday for first publication (November, 1831). Moreover, Faraday sought and sensed the unity of all electric phenomena and presented a much clearer picture of the whole process. The naming of the unit of inductance for Henry and the unit of quantity for Faraday is probably equitable.

Faraday had contributed very little before he was forty, but for his achievement after August, 1831, Magie has said that the record of his life presents the largest and most important contribution ever made to science by an experimental physicist.

By rapid steps he proceeded to "convert magnetism into electricity," as designated in his notebook nine years previously. First he wound two separate coils on a wooden insulator, expecting to produce a steady current in the second coil by an unvarying current in the neighboring coil. But this did not happen. There was only a mere kick of the galvanometer at the instant of starting or stopping the battery current. If the coil with battery current were quickly approached to the other coil there was a current induced during the motion. On August 29[1] he welded the ends of an iron rod together so as to form a ring. Separate copper coils were wound on opposite sides of the ring. The coil on one side was connected to a galvanometer, and the other to a battery. There was now no doubt about the realness of the induced current at the instant of making or breaking the battery current. Clearly the current was induced only when the magnetic field was changing. He then tried a straight iron bar with two separate and distinct coils. If it were a changing magnetic field that produced the current, then he should be able to detect a current by thrusting a magnet into the closed coil. This proved correct. Next he obtained these effects on a larger scale, using a powerful permanent magnet. These experiments enabled him to explain the mysterious Arago disc experiment. Moreover, he was able to rotate the copper disc between the poles of the large horseshoe magnet and obtain a steady flow of current in a galvanometer connected between the axis and the rim of the disc. The current was reversed by reversing the direction of rotation. He then proceeded to outline explicit rules for mag-



ONE OF HENRY'S ELECTROMAGNETS

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[1] Lord Rutherford states that Faraday's order of experimentation was with the ring first. (*London Times*, September 21, 1931.)

netic induction and first used the term "lines of magnetic induction."

Henry enjoyed a well-rounded lot of human experiences, but he was not generally chasing rabbits. The stage left the usual mark. He was obviously keenly interested in making and demonstrating the biggest magnet as well as in learning the technique. He would not have declined the prestige and honor of the Princeton professorship, even had his duties at Albany been purely research. As secretary of the Smithsonian Institution he probably had power and fame unequaled by any scientific man of his day. Almost by the time he was full grown, he had become instrumental in developing the two most important phases of our Machine Age, power and wire communication. Also he made a near approach to the discovery of radio waves when he magnetized a needle by placing it in a circuit distant from another circuit carrying an oscillating current. If Faraday may have been intuitive in his approach, one may ascribe to Henry the inspirational approach. As Sir William Bragg has said, Faraday was constantly seeking the simple unity of things. This applied not only to static, current and galvanic electricity, magnetism, light and matter, but also to gravitation. It is safe to say that if he had realized the relation between gravitation and electricity, it would have been expressed in a meaningful language.

The foregoing is merely an introduction to the lives of Michael Faraday and Joseph Henry, as a centennial greeting to the Royal Institution. It is not intended as a specific allocation on the scale of the immortals.

F. C. Brown

THE SCIENTIFIC MONTHLY

DECEMBER, 1931

MICHAEL FARADAY[1]

By Sir **WILLIAM H. BRAGG**, K.B.E., F.R.S., D.C.L.
DIRECTOR OF THE ROYAL INSTITUTION OF GREAT BRITAIN

I AM to speak to you to-night of Michael Faraday, of whom we shall hear much during the coming year. For he was one of the greatest experimental philosophers that ever appeared in this country or indeed in all the world; and of his discoveries none has had more consequences than that which he made in 1831, a hundred years ago. It was then that he found the true relation between magnetism and electricity. On this relation and on others, which he discovered in a few following years of intense thought and labor, have been founded all those applications of electricity which form the muscles and nerves of our modern life. How many and great these are we may realize if we think of the consequences of stopping every electric current that is running at this moment, so that we bring to an end all electric distribution of light and power, all transmission of news by telegraph and telephone, and a hundred other uses of electricity on which we have learned to rely. The very means by which I am addressing you to-night, the microphone that stands before me, the machine that transfers its vibrations to the ether, the receiver and the loud speaker which are beside you, are all constructed on principles first enunciated by Faraday; the whole mechanism and conception of broadcasting can be traced back directly to his work. Very few men have changed the face of the world as Faraday has done.

The most striking of his discoveries was made in 1831, and since it has led to the development of the electrical industries of every kind, electrical engineers of all countries are joining in centenary celebrations, of which the principal is to be held in London in September, next. The most public feature will be the fourteen days' exhibition which is to be held in the Albert Hall, beginning on September 23. It is to be arranged conjointly by the Royal Institution, where Faraday lived and worked, and by the Institution of Electrical Engineers, the latter body generously supplying the necessary funds. And since other discoveries of Faraday have been the foundation of some of our greatest chemical industries, English chemists are also taking their share of the enterprise and of the cost.

OUR DEBT TO FARADAY

This display will emphasize the great industrial consequences of Faraday's researches. Yet if I am to keep matters in their true proportion, I must at once add other reasons for the general wish to acknowledge our debt to Faraday. Though he described himself as being

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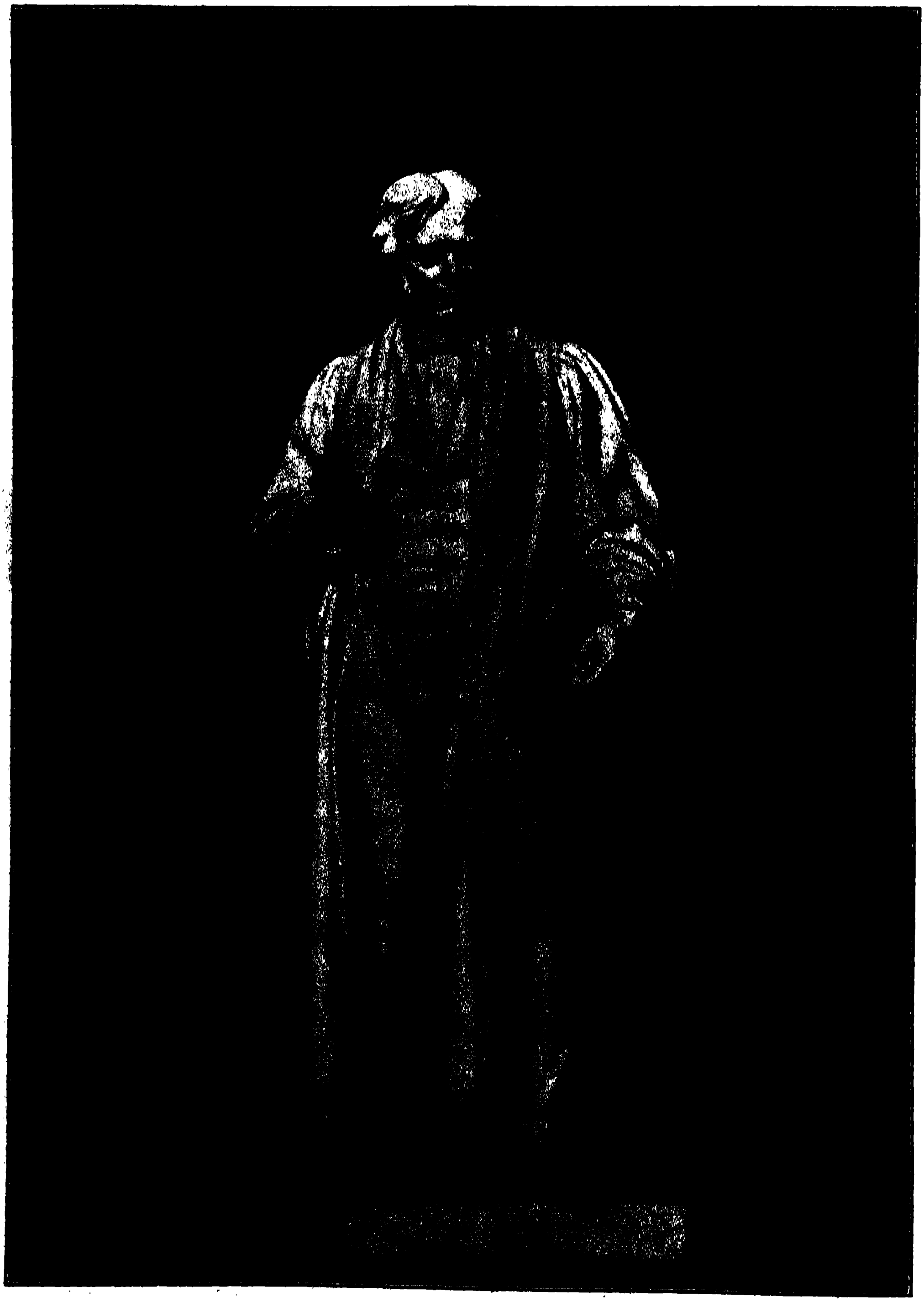
[1] A Broadcast National Lecture delivered on March 4, 1931, under the auspices of the British Broadcasting Company.



MICHAEL FARADAY

A STATUE BY FOLEY IN THE ENTRANCE HALL OF THE ROYAL INSTITUTION.

nothing else than an experimental philosopher it came about as a necessary consequence of his experiments that he modified profoundly the basic principles of scientific thought. He not only laid the foundation of some of the greatest and most successful of our industries, he also drew from his experiments clear-cut deductions which have made modern science possible and have led towards the strange and fascinating concepts of the physics of to-day. He has modified not only our mode of life but also our ways of thinking.

Yet another cause of our admiration lies in the extraordinary affection with which he is still regarded. Presumably this is a survival of the feelings of his contemporaries: how strong that must have been is evidenced by its persistence. During the last few months of preliminary preparation for the coming centenary, it has been a constant surprise to find that every one interested in science, in other countries as well as in this, entered gladly into the spirit of the proposals, not only because the significance of Faraday's work is well understood, but also because the memory of the man himself still has its charm.

And now I must speak rather more particularly of his life and his work: I must describe the nature of his discoveries in broad outline and I must try to sketch the man himself. I hope I may be able to show you how proud we have the right to be of this countryman of ours and how the spirit in which he set about his work was that before which difficulties always tend to disappear; how he was just the man whose example can be the greatest encouragement in the difficult times through which we are passing.

EARLY YEARS

Faraday began his working life in 1804, being then thirteen years old, as an errand boy to a Mr. Riebau, a newspaper agent and bookbinder in Blandford Street, near Manchester Square, London. It was his duty to carry round the news sheet of the day to the various subscribers in turn, giving to each person the time allotted for his reading of it. Faraday is said to have had a tender spot for newspaper boys ever afterwards. A year later he was bound to Mr. Riebau as an apprentice. Professor Tyndall relates that, many years afterwards, Faraday pointed out to him, in the course of a walk which they took together, the spot in the shop where he used to work at his bookbinding. Until quite lately the shop front was still in existence.

The handling of the books gave Faraday opportunities to read which otherwise could never have been his. Until he thus began to teach himself, he had had but the scantiest instruction in arithmetic and grammar. He made his bench his school; and it is very interesting to see what he learned there. Picture the boy, with an acute mind absorbed in the acquirement of knowledge and ill-furnished with it at the outset, gathering all that he could from the volumes that passed through the bookbinder's shop. Some of them were scientific works in which he took the deepest interest. He himself says that he delighted particularly in Marcet's "Conversations in Chemistry"; that Watts' "On the Mind" first made him think, and that his attention was turned to science by the article "Electricity," in an encyclopedia which he was employed to bind.

It is easy to imagine that the beauty of Faraday's style of writing, its clearness, strength and rhythm, were due to the literature which he encountered in this way, and attempted to copy. In all the books that he read he would meet with little that did not conform to the mature style of that day; there was no light literature of the modern kind. It is not surprising to find that the copious

MICHAEL FARADAY AND HIS WIFE

letters which the self-taught young man wrote to his friends seem to emulate the polished and balanced sentences of the *Spectator* or "The Vicar of Wakefield." Take the following from a letter to his friend Abbott, written when he was twenty:

> Let me notice, before I cease from praising and recommending epistolary correspondence, that the great Dr. Isaac Watts (great in all the methods respecting the attainment of learning) recommends it as a very effectual method of improving the mind of the person who writes and the person who receives. Not to forget, too, another strong instance in favour of the practice, I will merely call to your mind the correspondence that passed between Lord Chesterfield and his son. In general, I do not approve of the moral tendency of Lord Chesterfield's letters, but I heartily agree with him respecting the utility of a written correspondence. It, like many other good things, can be made to suffer an abuse, but that is no effectual argument against its good effects.

FINDING HIS WAY THROUGH

It would not be fair to find fault with the apparent sententiousness of such a passage as this. Faraday was in the absorbent stage and had made great use of his opportunities, drinking in knowledge and ideas from every source available to him. When in later years he had to explain to the world the results of his own experiments, and the deductions which he made from them, the first heaviness disappeared. His writings became models of good and restrained expression, which kept all the qualities he had admired in his youth: every lover of science knows their charm.

DAVY'S INFLUENCE

In 1812 came an opportunity of attending a course of lectures given by Sir Humphry Davy at the Royal Institution. Sir Humphry was then at the height of his fame as a chemist and a lecturer, and his discourses were social events. Faraday took copious notes of a set of lectures on chemistry, one of them on chlorine. This remarkable gas had only recently been isolated and was one of the scientific wonders of the day. Faraday made a fair copy of his notes and bound the beautifully written pages into a volume which he sent to Davy. This book is now one of the greatest treasures in the Royal Institution. Davy was much pleased, but when asked by Faraday if there were any vacant post at the institution he could only say no, for, however he might have liked Faraday as an assistant, the institution was much too poor to find wages for him. It happened, however, not long afterwards that Davy found grave fault with his only laboratory servant and dismissed him on the spot. As the result a carriage and pair invaded Weymouth Street, where Faraday then lodged. A footman descended and took in a note to "Mr. Faraday," which resulted in his engagement next day as assistant to Davy at 25 shillings a week with two rooms in the institution. This was the beginning of Faraday's scientific career. In the quiet laboratories in the basement of the Royal Institution he helped Davy to continue his chemical investigations.

A great experience awaited him in October of the same year, 1813. Sir Humphry and Lady Davy went on the grand tour of Europe, which was to last for a year and a half and to take in some of the greatest sights and the finest scenery on the Continent. Moreover, to the great contentment of Faraday, who went as assistant and amanuensis, visits were to be paid to many of the famous laboratories. In Paris, Davy and Faraday studied with immense interest the new substance, iodine; in Florence they burnt diamonds by means of the concentrated rays of the sun in the laboratory of the Grand Duke; at Rome they were shown experiments on magnetism; at Geneva, on the heat of the sun's invisible rays.

Faraday was a great letter writer, principally to his mother and his young friends, so that the events of the journey are well and fully recorded. So also is the joy of the home-coming in 1815. Once more the pair settled down to steady work at the Royal Institution; but as the years went by Faraday took a greater and greater share of it and, when Davy died in 1829, Faraday was appointed director of the laboratories and all the responsibilities for the work of the Royal Institution devolved upon him.

I must refer to two famous pieces of work which belong to these years. The first, in 1823, was the condensation of chlorine into a liquid, one of the early events in the story of the liquefaction of gases now so great a matter both in pure science and in industry. The story goes that Faraday was experimenting with chlorine and had sealed up a portion of the substance in its usual gaseous state, confining it in a closed glass tube. It happened that a very high pressure had been reached in the process. A little of the gas condensed and formed a patch of oily liquid within the tube. An interested visitor to the laboratory remarked that the tube must be dirty, a friendly insult which had to be washed out by a thorough examination of the circumstances. Next day Faraday was able to say that the oily liquid was condensed chlorine. Several other gases were similarly liquefied, but the more difficult gases—oxygen, nitrogen, hydrogen—were beyond the means available at that time. Though Faraday subsequently discovered that chlorine had already been liquefied by Northsmore in 1805, a fact which he hastened to acknowledge, yet his own researches on this subject were of great importance. The work was a notable contribution to the knowledge of a subject which is of high theoretical value and is the main principle of the refrigerating industries.

The other discovery of this period was that of benzene. It was then the custom to supply illuminating gas under compression in iron cylinders. Faraday's brother was actually one of the men engaged in the house-to-house delivery and collection. The cylinders returned as empty contained a small quantity of a fluid which Faraday examined. From it he isolated a substance of which he determined the constitution to be, by weight, twelve parts of carbon to one of hydrogen. He named it bicarburet of hydrogen: we now call it benzene. A little of the first liquid which he thus obtained is still preserved in the Royal Institution. Now, as is well known to many, this substance is the basis of half organic chemistry, and in particular of modern dyes. Faraday did not, it is true, make these dyes, nor did he come to a knowledge of those further developments and processes, due to the great organic chemists of the nineteenth century, which finally led to the establishment of the dye industry. But Faraday's part of the work is gratefully recognized by chemists as that of their pioneer. On the centenary of the discovery of benzene six years ago, a large meeting was held in order to record their debt. Perhaps the most striking way by which to draw general attention to the greatness of this work is to point to the recent excited discussion over the renewal of the dyestuffs act, of which it may justly be said that the point at issue was whether or no it was for the good of the country that our people should be given favored opportunities for the manufacture of the products derived from Faraday's bicarburet of hydrogen.

EXPERIMENTS WITH ELECTRICITY

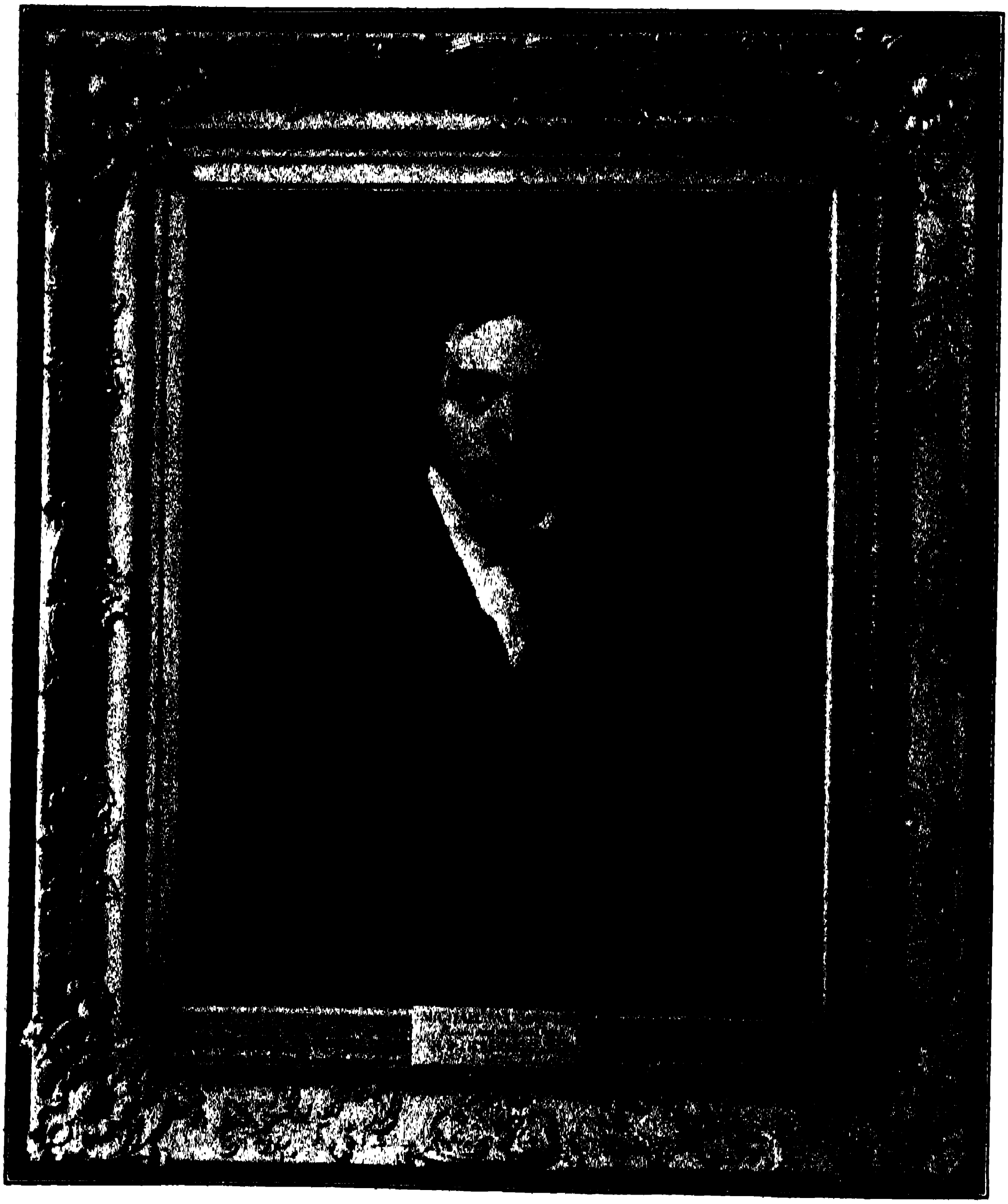
Now we come to the famous electrical discoveries made in the half dozen years of which 1831 was the first. Let me try to explain their significance.

The first of these discoveries gave us the means by which, in these days, we produce electric currents. There is no need to enlarge on the extent to which the electric current is used in modern life. But in those days electricity was a philosopher's toy. Even the curious experimenter who wished to generate electricity must employ the cumbersome old machines in which charges were developed by rubbing plates or cylinders of glass, or he must make use of the expensive primary batteries consisting of metals acted upon by acids. There was no such thing as insulated wire to be bought: it had to be made in rough and ready ways in the laboratory.

Now there had for some time been prevalent an idea that it might be possible to generate electric currents, by means of what men called induction. The principle was simple enough. A magnet, as was well known, transformed any neighboring piece of iron into at least a temporary magnet, though the iron had previously shown no traces of being magnetic until the primary magnet "induced" it to become one. The induced magnetism persisted in the iron as long as the proximity was maintained. So also an electrified metal sphere "induced" charges upon any neighboring metal sphere, though the latter might be previously uncharged. Again the induced charge persisted so long as the spheres were neighbors. Then, it was asked, might it not be expected by analogy that if a wire along which a current ran steadily in one direction lay alongside another wire which was capable of carrying a current, induction would cause a current to run in the second wire so long as it ran in the first? We may be sure the effect was often looked for. It is easy to say now that, of course, nothing of the sort should happen. Faraday himself made many electromagnetic experiments without hitting on the truth. But on August 29, 1831, he made the great discovery, which is so simple that it does not seem possible to make the telling of it dramatic. The same difficulty stands before us in the matter of the Centenary Exhibition at the Albert Hall. We are to have a statue of Faraday in the center with his first apparatus about his feet while the fruits of his experiments line the walls and the connecting links run between like the spokes of a wheel. But when we make up the old experiments or take down the original pieces of apparatus, if we have them, from the cases where they are carefully preserved, the few pieces of wire and tape and string and iron look so insignificant that we might become afraid. Surely, however, those who see these little things will ponder on their meaning and give us that imagination without which any effort to kindle enthusiasm is like putting a match to an empty grate.

A SIMPLE EXPERIMENT—

When Faraday, on August 29, 1831, tried the experiment of electric current induction as others besides himself had tried before, but now by a new and most aptly devised method, he found that the expected induction was there but not quite in the expected form. A current ran in the second wire, while the current was being started in the first: as soon as the current in the first wire reached its full strength and became steady there was no further current in the second. But when the current of the first wire was being stopped there was again a current in the second which ran until the stopping was over. In other words, a steady current has not the power to induce. It is only a changing current that can do it, and that is the whole story. By subsequent experiments Faraday widened and clarified his first ideas. He soon made it clear that it was equally effective if the position of the first wire was undergoing change while its current remained steady, or if again a magnet were brought near the second



MICHAEL FARADAY

AT THIRTY-NINE YEARS OF AGE. A PORTRAIT PAINTED BY H. W. PICKERSGILL.

wire; because all these different actions were but variants of one, namely, an alteration of the magnetic conditions in the space near the second wire. In Faraday's mind the space about a magnet, whether a permanent steel magnet or an electromagnet such as he wound in numbers for himself, using his home-prepared wire, was in some way affected, so that it was abnormal: and he imagined that this state varied in intensity from point to point. He was very curious about this condition: he scattered iron filings over a sheet of paper lying over the magnet and watched them as they arranged themselves in elegant lines, thinking so to come to some ideas about that condition, just as the marks on the sand may show which way the tide has run. These material lines were to him the visible signs of "lines of force" in space, as he called them, and as electricians have called them ever since. So we may make the great statement in yet another simple and comprehensive way. As long as there is change proceeding in the magnetic conditions of any space there will be a tendency for currents to run in a conductor embedded in that space. It is necessary to say tendency, for, of course, the conducting circuit might not be complete, so that no current could get round it, however great the tendency might be.

So if we move magnets past coils of wire we have the dynamo: and if we send electric currents alternately in opposite ways round one coil of wire we may generate alternating currents in neighboring coils and we have the transformer; and so the whole family of electromagnetic devices. That is all. It is a very simple conception on which to build so greatly.

—And Its Consequences

But there is even more in this than the foundation of industries employing millions of men. For here begins one of those great sweeps of thought that form the winding road by which research makes its way into the unknown. Faraday had conceived the idea that the space about the magnet was the seat of the working of those laws whose effects his experiments revealed to him. The iron and the copper wire were to him no longer the repositories of the powers whose actions he observed. These lay in the invisible tenuous space of which the materials in use might be considered to be the boundaries. He drew away from the older idea that magnets acted on one another across a space which was not concerned in the action. He began to think that on the contrary this space or a medium which filled it was the real seat of power. It was a breakaway from the material to the immaterial. The idea has been extraordinarily fruitful, first in Faraday's hands and then in the hands of Clerk Maxwell and other great men who followed him. It is true that the road has turned other corners since then. But what Faraday did has still its immense consequences, not only on the practice but also on the thought of our own times.

The wish to make these things clearer to himself was one of the reasons that prompted him to undertake a second set of experiments of fundamental importance. These related to the mutual attractions and repulsions of electrified bodies. He wanted to know whether in this case also the medium played a principal part. A conductor could be charged with electricity. What did charging mean, and where was the electricity? Was it on the surface, or was it distributed through the interior or was it partly outside and partly inside? There were appearances that suggested the importance of surfaces generally. Would it be good, therefore, to pack a hollow globe with a quantity of tin foil, which certainly had plenty of surface? Such a globe might more readily receive a charge of electricity when the tin foil was there than when it was not. Comparison might be made with the effect of filling the globe with water. But he found no such differences. He tried a great number of experiments of this kind. In some of them he used a large boiler which he had obtained from the coppersmith's. He mounted it on insulating supports and charged it with electricity. He then tried to find what proportion of the charge was to be found within. His final experiment, made on January 15, 1836, was the construction of a great cube with an edge of 12 feet, made of a light framework, over which he stretched a covering lined with conducting material. It was set up in the theater of the Royal Institution and blocked up the center to the level of the gallery. It rested on insulating supports so that when connected with an electrostatic machine it could be charged with electricity until sparks flew from it and brushes glowed at every outside corner and projection. Faraday was inside the cube while this was going on and was in perfect electrical peace: his most delicate detectors of electricity showed no sign of disturbance.

This was the climax of a series of experiments which answered for him his question. The power that is displayed in the attractions and repulsions of electrified bodies or in the electric spark does not lie in those bodies. It is seated in the surrounding space, of which the bodies may be regarded as boundaries: he had held a similar belief as regards magnetic effects. That is why nothing electrical happens inside an electrified conductor. That is why Faraday could sit peacefully inside his cube while electrical storms raged outside. His case was a perfect lightning conductor or rather protector from lightning. His experiment showed that energy could be stored in the space between two conductors differently charged with electricity. This is the principle of the so-called (and very badly called) condenser. How important this discovery has been every electrical engineer knows well, whether he deals with the distribution of alternating currents or with submarine cables, or wireless, or, indeed, with the majority of the applications of electricity.

Now it may be argued that Faraday's experiments can nowadays be interpreted in different terms. That is not of the least consequence. Faraday's interpretations were a new presentation of the whole matter, illuminating and fruitful in the highest degree. What he saw and put into his own language is there still, and will be there for all time. Faraday's mode of thought supposed the existence of a space-filling medium which could be the seat of his magnetic and electric forces. We speak of this medium as the "ether." Clerk Maxwell, whose centenary is to be celebrated at Cambridge this year, showed that the ether which Faraday described so as to satisfy his experiments must be able to carry waves, and he framed the famous hypothesis that light itself was simply an electromagnetic disturbance traveling through the ether as a wave travels over the surface of the sea; or a sound wave through the air. We are using such ether waves at this moment. The ether of Faraday and Maxwell is as useful as ever, even though there are newer and bolder flights of thought which express themselves without it.

ARGUING FROM UNITY

Thus Faraday threw all magnetic and electric actions into his medium. It would not appear to him that confusion might be introduced by doing so, and Maxwell's development of his ideas was their justification. We shall better understand his thought in this respect, and, indeed, the whole movement of his mind, if we consider the vision that urged him forward. He had a fundamental belief in the unity of nature's manifestations. Light, heat, magnetism, electricity, chemical action, gravity, cohesion and so on, must somehow, he thought, be interconnected. Many such mutual relations were, of course, known in Faraday's day: heat, for example, could influence chemical action. But Faraday had more in his mind than the existence of a limited series of separate links. In pagan days men raised up a little god to rule independently over every separate manifestation of nature —sunshine and wind and rain, lightning and thunder. As thought broadened the little powers became aspects of a greater majesty. The world became one kingdom. To Faraday it seemed that the laws of such a kingdom must bear a common impress and be interwoven in their effects. Whatever electricity was, or sunshine, or chemical action, surely their operations could not be independent; electricity, for example, must be connected with magnetism, with chemistry, with gravity and so on. To look for the connections must be a fundamental inquiry. Indeed, it would not be wrong to sum up the greater part of Faraday's scientific activities as an endeavor to join all nature's manifestations together, to bind the parts into one great whole. It was in this spirit that he hacked his way through endless labors and dull details so often to emerge triumphant at last. Sometimes he failed where others have succeeded in later years.

These two great experiments that I have described, the first on the generation of current by magnetic induction, the second on the seat of electrostatic force, were the important members of a long series by which Faraday worked out the laws that govern the construction of electric devices. They may be said to be represented by the two quantities, inductance and capacity, which are the chief immaterial contents of the wireless set. Their relative adjustment constitutes "tuning in." And that which is thus made capable of reception is the "wave" which Maxwell described in precise detail as following necessarily on Faraday's work. But, of course, the wireless set is very far indeed from being the solitary example of the application of Faraday's principles.

IN THE SCIENTIST'S LABORATORY

I should like to tell you very briefly of another research. I have said that Faraday put before himself as a main purpose the discovery of the connection, which he believed to exist, between every pair of the manifest forces of nature. He tried in 1845 to find some connection between magnetism and light, to find whether a light-ray could be affected in any way by his lines of electric or magnetic force. Imagine him standing in his quiet laboratory on the morning of September 13, 1845. He has already been at work for several days searching for any effect of electricity on light. He has filled many pages of his diary, but always at the end of the short description of each experiment he has been obliged to write "No effect." To-day he will try whether magnetism will serve him better. For magnetism he has magnets at his disposal, and for light there is daylight coming in through the windows and he can produce artificial light if he requires it. What shall he do first? Shall he allow a strong beam of light to fall on a piece of iron and then magnetize the iron in the hope that some change will appear in the light or the iron? He may try, but his means of observation are not powerful enough to give him a result. He goes about the matter in a more sensible way. If there is an effect which nobody in the world has ever seen before, it surely requires favorable circumstances and delicate observation. He will therefore use his great electromagnet, the strongest that he has. If light is to be affected, the quality or condition of the light which

FARADAY IN THE LECTURE THEATER OF THE ROYAL INSTITUTION

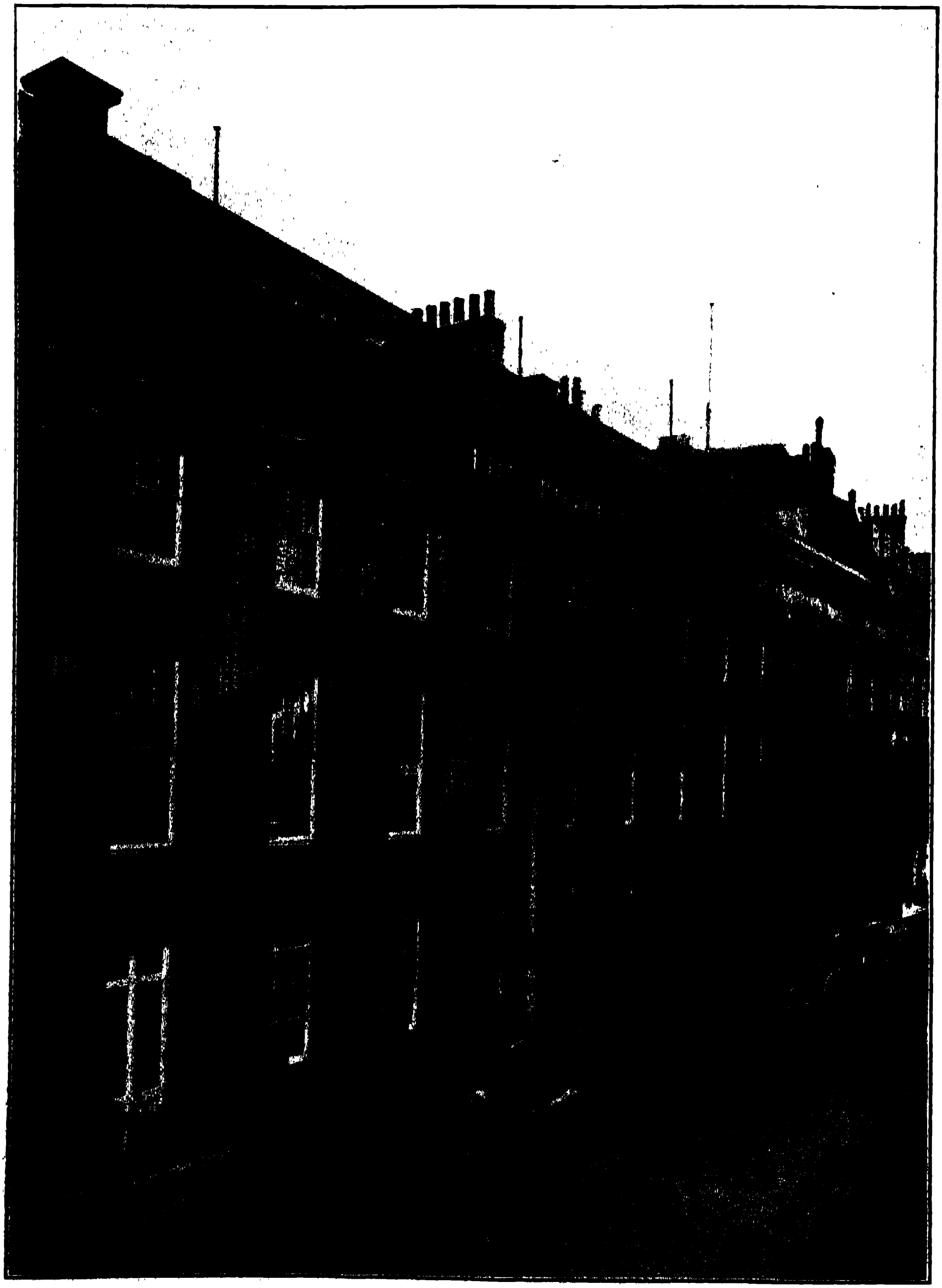
DELIVERING ONE OF THE CHRISTMAS JUVENILE LECTURES ON METALS.

he is most likely to watch with success must surely be one in which it is easy to detect change. Now there is one in which such detection is extremely easy. He must use polarized light: that is to say, light in which the ether vibrations are not taking place in every possible direction perpendicular to the ray, as they are usually, but are confined to one such direction indicated by what is known as the plane of polarization. The early years of the nineteenth century had been full of investigations of light in its polarized form. At the Royal Institution itself, Thomas Young, one of the foremost thinkers in the subject, had taught and worked. Polarized light is common enough in nature, as, for example, the light from the sky; and the physicist can produce it in various ways at will. Faraday produces such a ray of polarized light and adjusts his instruments to the determination of the plane of polarization, an observation which can be made with great accuracy. He makes his ray skim the surfaces of his magnet poles and turns on the current that makes the poles active. There is no result. He enters the fact carefully in the diary. He rearranges his poles, alters his ray, makes it traverse various transparent substances while near the poles, and in many ways he looks for an arrangement which will show him what he seeks. For some time the day is no more successful than the days that have gone before. What could have kept him to his patient search but conviction that it was reasonable to hope for a result? And if one should appear he would see for the first time a vision of one of the great laws of the universe. He was well aware of the significance of his search.

A Triumphant Entry

And then there *is* a result. A particular arrangement of the magnet, a particular adjustment of the light, a special piece of glass through which the light has to go: it is a heavy glass taken from a batch prepared while working at glass under a government commission. And when he turns the current on to the magnet the plane of polarization moves, a glimmer of light appears in the optical arrangement which has been adjusted to darkness when the electric current was off. It is delightful to see in the diary the expression of his joy. "But," in capital letters underlined, "when . . . such and such arrangements were made . . . there was an effect produced on the polarized ray and thus magnetic force and light were proved to have relations to each other." There is in this case no outstanding industrial development of his new discovery, but it was to him, and is to us, another of the links that bind nature's forces into one.

His attempts to connect gravitation with electricity or heat are of the same character: their interest is none the less because they failed completely. Faraday leaves us a record of his feelings as he entered the empty lecture theater from the high roof of which he intended to drop coils of wire which might possibly be found to be carrying currents on their way down. "It was almost with a feeling of awe . . ." he writes at the beginning of the note in his diary. It happened, curiously enough, that for many days he believed he had found what he looked for: but his effect was spurious. Indeed, it was impossible that he should be successful. It was not until Einstein had developed his theory of relativity and the astronomers had carefully measured up their observations of the eclipse in Brazil that a true effect was found. Then it was clear that the ray from a star had been *bent* by going close to the sun. Electromagnetic waves had been turned aside by the gravitational forces of the sun's mass. Gravity and light were linked together.



THE ROYAL INSTITUTION IN LONDON

WHERE FARADAY DISCOVERED THE RELATION BETWEEN MAGNETISM AND ELECTRICITY.

Faraday could never have found any such effect, though he was sure that something was there to be found and returned often to the search for it.

I have now said enough, I believe, to give an idea of the nature of the problems which Faraday attacked, and of his reasonings and methods, though I have referred only to a very few of the things which he did. I have said nothing, for example, of his tremendously important work on the connection between electricity and chemistry. This work may be described as having established the atomic theory of electricity and, indeed, as having foreshadowed the electron. It laid down the laws of electrolytic action and made a notable addition to the chemical knowledge of the atom and the molecule. It is the basis of some of the most important electrochemical industries of modern time.

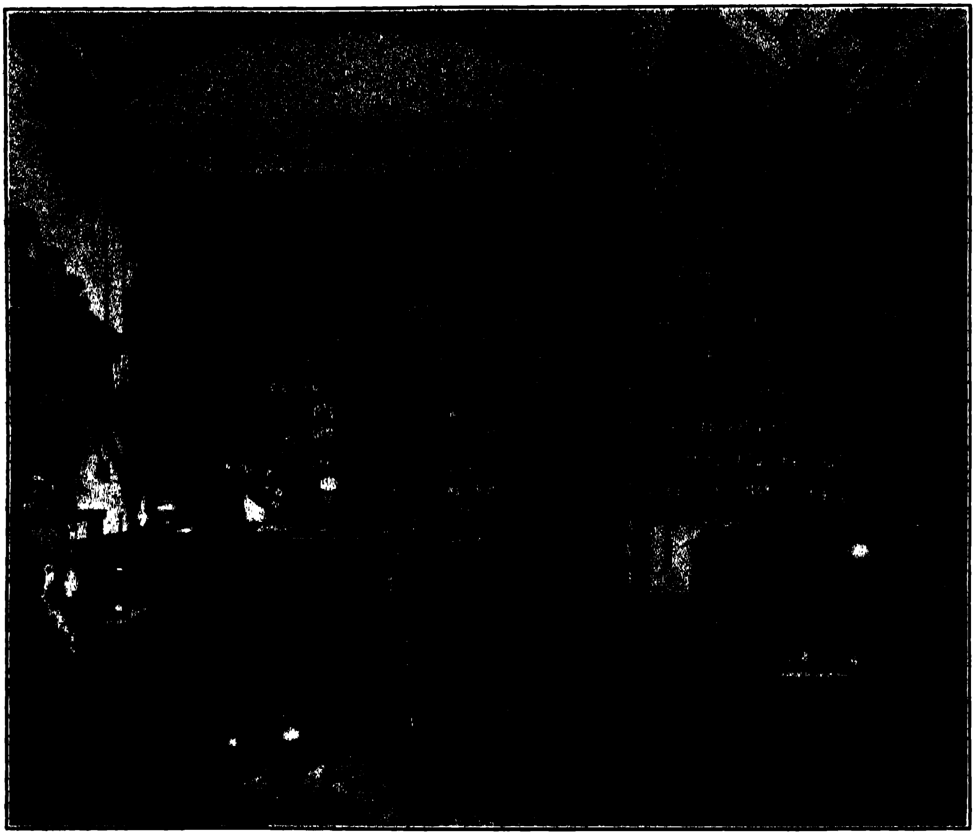
THE LECTURER AND MAN

When the knowledge of Faraday's work became general in the scientific circles of Europe, principally through his publications in the journals of the Royal Society, and when its value came to be perceived, he became a notable figure. But at home he had yet another mode of entry into men's regard. He lectured in the theater of the Royal Institution with such clearness and power, such simplicity and charm, that tradition, now speaking but rarely at first hand, still passes on the most reverent and affectionate memories. The courses of lectures which he gave so often at Christmas, nineteen times in all, to "Members of a juvenile auditory," as the old phrase has it, would alone have made him and the Royal Institution famous. Sir Alfred Yarrow, the famous shipbuilder, one of the few now living who went to his lectures, has told me how he and his boy friends so loved a word with the old man that they used to waylay him on Sunday on his way to church. And having benefited by one lot of kindly greetings they would let him walk on, but themselves run by back streets to intercept him again.

He took a great and helpful interest in the scientific affairs of the nation. Even in his earlier days his reputation as an experimenter and thinker brought to him many who wanted his help and advice. He could indeed have built up a lucrative consulting practice, but refrained because he wanted his time and energies for his researches. His decision was marked by a drop in his income from fees, from over £1,100 in one year to £160 in the next. But he responded generously to suggestions that he should place his scientific abilities at the service of the state. There was in the eighteen-twenties no little anxiety as to the state of the glass industry, particularly in respect to glass of high quality. Faraday formed one of a small working committee set up to make experiments. They worked first in Camberwell, but subsequently a glass furnace was built for Faraday in the Royal Institution. Very interesting work was done, though nothing emerged of immediate practical application. Some remarkable glasses were made and the whole labor and cost were indeed covered by the striking use which Faraday was able to make of some of the glasses in his subsequent researches. I have already spoken of one of them.

SERVICE TO THE STATE

Faraday was consulted by the government in respect to mining dangers, and was indeed one of the first to point out the explosive character of suspensions of coal dust in the air. But his most extensive and continuous service to the state was rendered as scientific adviser to the Trinity House, which post he occupied during the greater part of his life. This body takes charge of the lighthouses. It is interesting to observe



FARADAY AT WORK

IN HIS OLD LABORATORY AT THE ROYAL INSTITUTION. FROM A CONTEMPORARY WATER COLOR.

that he saw the gradual replacement of the old oil-burning lanterns by the electric machinery which he himself had made possible. He appears, however, to have been very cautious in the matter, and to have asked for exhaustive trials rather than to have pressed impatiently for progress. Even when he was over seventy he was still making trips by sea in order that he might have the material for his reports. For this work he received a certain pay, but it was extremely moderate in amount, perhaps because he himself did not ask for more. He writes to the deputy master of Trinity House:

> In consequence of the goodwill and confidence of all around me, I can at any moment convert my time into money, but I do not require more of the latter than is sufficient for necessary purposes. The sum, therefore, of £200 is quite enough in itself, but not if it is to be the indicator of the character of the appointment; but I think you do not view it so, and that you and I understand each other in that respect.

He certainly received at no time a worthy pay from the managers of the Royal Institution. On July 4, 1853, when he had been at the Royal Institution for forty years, the managers report to the general meeting that

> They have advanced the salary of Dr. Faraday from £100 to £300 per annum. . . . The financial condition to which the Institution was long reduced by these various disasters restrained former Committees of Managers from offering to Dr. Faraday that consistent remu-

FARADAY'S "GREAT" ELECTROMAGNET

neration which, as they were well aware, his intimate acquaintance with the state of the Institution would have then withheld him from accepting. But the effects of these disasters have now passed away, and the prosperity of the Institution is as permanently secured as is compatible with the condition of a society depending on public estimation. The Managers therefore now feel themselves fully justified in awarding to Dr. Faraday the only remuneration which it is in their power to bestow.

Thus Faraday grew not only to be a great figure in scientific circles but also to be a valued public servant. He may even be said to have been a figure in society life of the day. He was the first secretary of the Athenaeum Club. But his relations to society were one-sided. His discourses at the Royal Institution drew hearers of every class: the Prince Consort himself was a frequent attendant. He certainly admired Faraday himself, and we may well believe that he considered Faraday's work and influence to be of high value to the nation. But though society came to Faraday, Faraday did not go into society. This was not because he was unsociable. On the contrary, he was full of fun. I wonder what the staid managers of the Royal Institution thought of the parties when velocipedes were ridden round the corridors of the theater. His abstention from all society engagements except the meetings with a few intimate friends was due simply to the decision that he must concentrate on his principal work.

It would be absurd to think of these renunciations of money and social pleasures as marks of a foolish quixotism or an unhappy nature. From all such perversions Faraday was poles apart. He knew perfectly well what he was about. He was thoroughly happy in his work, which filled his mind with great visions. And he was just as happy in his private life, of which it is necessary that I should say something. If he had not been so content he could not have given his hearers so much delight and encouragement. *Punch* may have rallied him for his lack of a certain ambition:

Oh, Mr. Faraday, simple Mr. Faraday!
 Did you of enlightenment consider this an
  age?

THE HISTORIC RING OF SOFT IRON

WOUND WITH SEPARATE COILS OF COPPER WIRE CONNECTED TO BATTERY AND GALVANOMETER, RESPECTIVELY, USED BY FARADAY IN HIS FIRST SUCCESSFUL EXPERIMENT IN ELECTRO-MAGNETIC INDUCTION.

Bless your simplicity, deep in electricity,
But in social matters, unsophisticated sage!

—but the lines were surely written with a very kind smile and very deep respect. Of all the words in the English language the word "simplicity" has variations of meaning which differ most from one another: the simplicity of Faraday was of the kind which brings the other virtues in its train.

A chief contributor to the happiness of his private life was the wife whom he married as Sarah Bernard in 1821, when he was thirty. He was devoted to her. She does not appear to have demanded more than he gave her, or was able to give her in the mode of life which he chose. She must have satisfied him completely, because whenever he was away from her he wrote in terms that show how he turned to her; and when he passed through the long periods of overstrain which his eagerness brought upon him, she was his constant and beloved companion. There were no children.

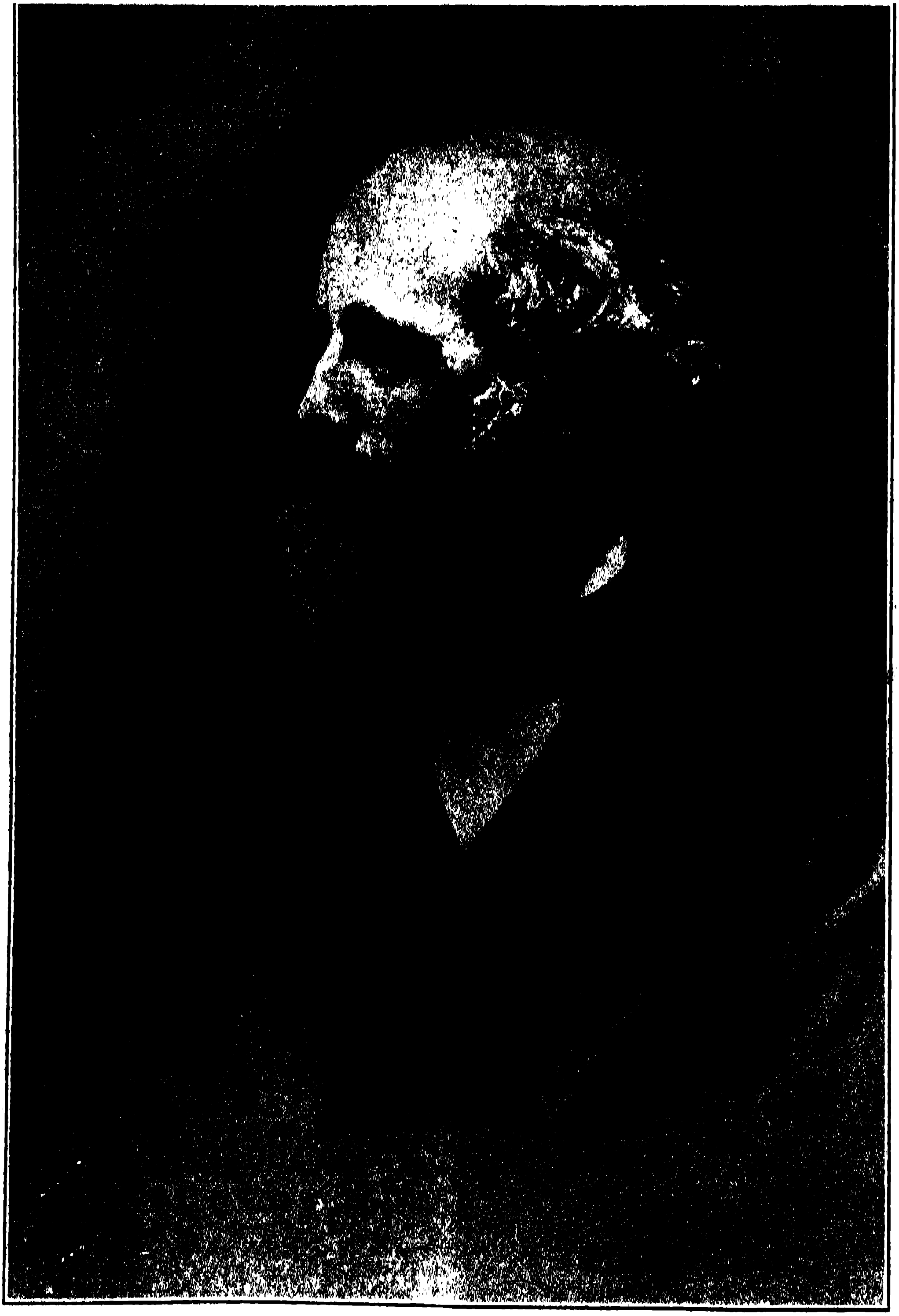
The only recurrent complaints that appear in Faraday's letters to his friends are in respect to his loss of memory and oppression by headaches. No doubt the burning excitement of his researches made him too little aware of bodily exhaustion. After the period of the first great electrical researches in 1831 to 1840 a long rest was necessary: and when in 1845 he tried to begin again he found he was hampered by inability to concentrate. Nevertheless, there were still great times before him. Only, as he grew older the bursts of activity became shorter and the necessary resting time longer. Wilhelm Ostwald, who has recently written a most interesting psychological study of Faraday, believes that it was his inability to trust his memory that led him to write his well-known diary, his day-by-day record of his work and deliberations and proposals for the future, interspersed with occasionally delightful little touches of jubilation or resigned disappointment. He began, however, to write his diary in his early days, when there was no evidence of distress, and the careful style changes very little as the years go by. Although his letters show that the loss of memory was severely felt as a hindrance to his work, it does not appear, according to his own account, to have affected his spirits.

Religious Beliefs

Lastly, I come to one of the most interesting aspects of Faraday's life: his religion. It would not be right to pass it by, as we may shrewdly believe that Faraday would have done had he been charged with the task of giving an account of himself. His attitude is clearly characteristic, and our chances of understanding him would be less if we paid no regard to it. Faraday was a member of a small and isolated sect known as Sandemanians, after their founder. Their beliefs implied a very simple form of worship: they demanded spiritual reverence, a close adherence to the teaching of the Scriptures, mutual help in matters of religion, and general charity. With this little body Faraday associated himself at the appointed times, cutting himself adrift, to outward appearance, from all his science. He did not even inform his wife of the moment when he made his profession of faith and was formally received into fellowship. He took his part in the worship, though, it is said, with a hesitation and difficulty that were totally absent in the lecture theater. The injunctions to charity were certainly fulfilled: it is known that he gave large sums away, though he kept no account whatever of his gifts as he kept careful records of his scientific work.

If this complete separation of his religion from his science seems strange, we must remember that it would not seem so strange to any of us if we could put ourselves back into his days: and I think it may be added that to some of us it would not seem strange even now, if we consider what Faraday may have meant by it. Remember that he himself was filled with a vision: he had actually been himself the first to see the workings of some of the great laws of the universe, and the unity of it all possessed him. Here were facts in natural accordance with the universal presence and power of the One God he had been taught to believe in. But his experiments could tell him nothing more of the qualities of that God. They fitted perfectly into their place, but they were trifles in comparison with the wider vision which he believed that his own spirit could ponder on and hope to see. This he sought in the quiet of his fellowship. We do not know, of course, to what extent he was satisfied. He was intensely reserved in religious matters: in answer to one correspondent he even deprecated religious discussion as generally unprofitable, but this was certainly a statement for a special occasion, and as a general expression of his attitude would go much too far. His attachment to a simple communion can cause us no surprise. He would, in the first place, be guided by his family tradition, and in the second place his own tastes were against any display. We ought not to go further in the attempt to see into Faraday's mind in religious matters: all that I may do legitimately is to give possible reasons for his very interesting attitude. For the rest Faraday was a very happy man, who was also a center of happiness, and we must judge by that.

It is Faraday's public life that belongs to us: it is one of the possessions of the nation, one of the great treasures. It is not only that his work has had such far-reaching consequences that all the world is affected by what he did, not only that he made plain the intricate connection between electricity and magnetism so that we are in daily dependence upon these forces of nature for the transfer of power and intelligence; it is not only that on his discoveries are now resting great British industries which are alive and are helping us through these difficult times. All these things are marvels so that we are proud of our famous countryman. But we all love the man himself for his simplicity of faith and purpose, for the breadth of his vision, and the humility of his thought, for his kindly generosity and for the light which he shed around him. He thought first of the quality of that which he gave, and only in the second place of that which he received in return. Could there be a nobler leading? Could there be any following more certain to bring us through times of depression and doubt to a triumphant ending?



JAMES CLERK MAXWELL

JAMES CLERK MAXWELL

(1831–1879)

By Dr. EDWIN H. HALL

EMERITUS PROFESSOR OF PHYSICS, HARVARD UNIVERSITY

THE scientific writings of Maxwell prove that he was one of the most potent intellects of his century. They, naturally, give no evidence, except an occasional gleam of humor,[1] of the fact that he was also one of the most genial and lovable of personalities.

Maxwell's paternal ancestors belonged to the "laird" class and to the intellectual aristocracy of Scotland. His mother's family, of Northumberland, were of like station and quality. There was legal ability and artistic talent on both sides of the house. The family name was originally Clerk,[2] but J. C. M.'s grandfather, George Clerk, added his wife's maiden name, Maxwell, as a condition for bringing a small landed estate into his family. J. C. M.'s father, John Clerk Maxwell, was a lawyer in Edinburgh, but upon his marriage he gave up the law and went to live on the Maxwell estate of Middlebie, later called Glenlair, in one of the southernmost counties of Scotland. His son was born in Edinburgh,[3] June 13, 1831, but the first ten years of the boy's life were spent at Glenlair, and his childhood speech had a very broad accent which, it seems, he never lost entirely. His mother died when he was eight years old. The father, who to the end of his life enjoyed an ideal intimacy with his son, had a great interest in all things mechanical and in all manufacturing processes, and this interest the son shared from his infancy. The boy was very active, both physically and mentally, and in all his activities there was a pronounced individuality. For gymnastics he rode a pony, became expert with a "leaping pole" (for crossing streams or other obstacles), learned to balance and paddle about in a floating wash-tub,[4] and practiced endlessly with a mechanical toy called "the devil on two sticks." This was a natural precursor of the famous "dynamical top" of his mature years. Another plaything was some form of whirling optical apparatus, for which he made drawings. This probably gave him the idea for his later "color-top" method of mixing color *impressions*, as distinguished from the mixing of *pigments*.

He was interested in and very sympathetic toward all manner of living creatures, and accordingly he, unlike his father in this, was no sportsman. He had a winning way with dogs, and in his later optical researches he could induce them to let him illuminate and examine their retinas, which he found very beautiful with patches of color. He read eagerly, intelligently and retentively, thus acquiring much knowledge without conscious effort; for example, a remarkable familiarity with the Bible. In spite of his abounding energy and high spirit he seems to have lived a blameless life throughout, with one exception. "One

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[1] For example, on p. 3 of his "Electricity and Magnetism," in suggesting the wave-length of a particular kind of light as a standard of length, he remarks, "Such a standard would be independent of any changes in the dimensions of the earth, and should be adopted by those who expect their writings to be more permanent than that body." In a sense this suggestion of Maxwell's was adopted about twenty years later in the precise measurement, by Michelson in Paris, of the wave-length of the red line in the spectrum of cadmium.

[2] John Clerk, "Lord Eldin of the Court of Sessions," was of this family.

[3] Most of the material used in this paper is taken from the "Life" written by Maxwell's intimate friend Campbell.

[4] The accompanying picture illustrating this accomplishment is from a drawing by Jemima Wedderburn, a cousin, on his father's side, some years older than J. C. M.

MAXWELL CROSSING A POOL IN A WASH-TUB
A SCENE FROM HIS BOYHOOD DAYS DRAWN BY ONE OF HIS COUSINS.

evening at Glenlair, just as the maidservant was coming in with the tea-tray, Jamsie blew out the light in the narrow passage, and lay down across the doorway.''

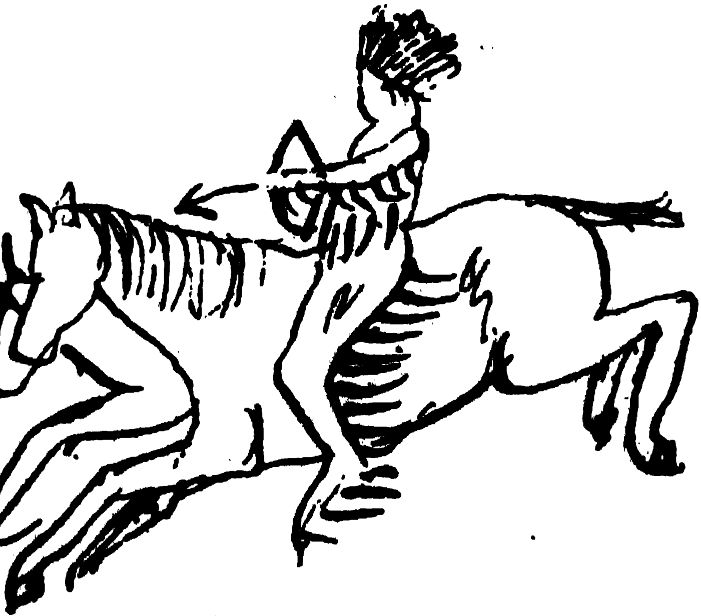
Young Maxwell's formal education began inauspiciously at Glenlair under a private tutor whose unwise and even brutal method of discipline produced in the boy, according to his biographer, ''a certain hesitation of manner and obliquity of reply which Maxwell was long in getting over, if, indeed, he ever quite got over them.'' I can not help suspecting, however, that this manner was due in some measure to a certain natural love of mystification, playful and rather engaging for the most part, in the boy he was and in the man he became. However that may be, when at the age of ten Maxwell entered Edinburgh Academy as a pupil, his somewhat odd behavior, combined with his rustic dress and speech, attracted the unfavorable attention of his fellow pupils, who proceeded to haze him in approved school-boy fashion and gave him a nickname, ''Daftie,'' which clung to him for a year or two at least. They even, at first, thought him rather dull. The boy, however, had too much spirit and self-respect to be depressed by this treatment, and before the six years of his academy life had passed his true quality was recognized by his associates.

He wrote frequently to his father during these years at Edinburgh, showing his affection not so much by protestations as by the frolicsome humor of his letters. One of these, written when he was not yet twelve years of age, seems worthy of especial comment. It is elaborately decorated on its margins with pen work and it contains a number of drawings. The first part of the text is printed, the last part is in script so written as ''to be read backwards through the paper.'' The letter begins with mention of a lecture which told how the American Indians kill buffalo by shooting them from horseback with a bow, and one of the drawings gives the boy's conception of this operation. This picture seems to me so remarkable that I have reproduced it here. The bow, of course, is absurdly small, meant to be so, and the backbone of the horse has apparently cut its way to the rider's waist-line. But the rider's legs grip the horse's body easily and securely, and every joint of the horse's legs is shown flexed in natural action. When it is remembered that this drawing was made by a boy of eleven years, a whole generation before instantaneous photography began to be used in the study of animal locomotion, the evidence of *action*, the sense of mechanical *func-*

tion, which this figure of the horse shows is astonishing. Let any one who is inclined to question this statement study the next set of old English hunting-scenes that may come to his attention and see whether he can find the figure of a running horse represented in any other attitude than that of a child's rocking-horse, forelegs extended forward, hind legs extended backward, the farther the better.

As a boy and as a man Maxwell was fond of writing verse, usually humorous verse, and in the Academy he excelled in English. He stood well in Latin also, but concerning the composition of Latin verse he writes to his father, "When I lithp in numberth it ith but a lithp, for the numberth do not come." In mathematics at the Academy he stood in a class by himself. Before he was fifteen years old he had written a paper describing a method of drawing ovals of various kinds, and this paper was by Professor Forbes and Professor Kelland, of Edinburgh University, so well thought of that it was presented at a meeting of the Royal Society of Edinburgh with favorable comment.[5]

Maxwell entered the University of Edinburgh in 1847, when he was sixteen years old, and he remained there three years. He found competent men in the chairs of physics, chemistry and mathematics, and he studied with all of them, maintaining his interest in matters of science but with no great pressure of attention. In fact, it appears from Campbell's "Life" that Sir William Hamilton,[6] professor of mental philosophy, made a more profound impression upon Maxwell's mind than any other of his Edinburgh teachers. He attended also lectures given by the professor of moral philosophy, John Wilson, better known as Christopher North, the name


A SKETCH MADE BY MAXWELL WHEN HE WAS ELEVEN YEARS OLD

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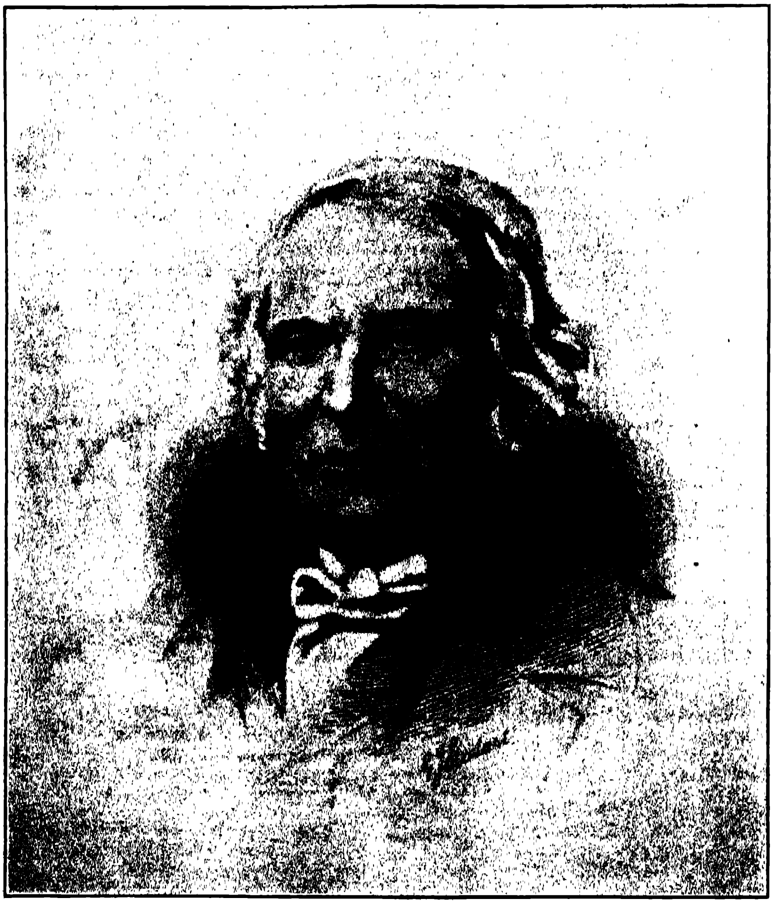
[5] The paper was entirely original with Maxwell, though it was finally discovered that Descartes had drawn ovals in the same way.

[6] Not to be mistaken for his contemporary Sir William Rowan Hamilton, the famous Irish mathematician. In drawing up a plan of future study, at the end of his course at Edinburgh, Maxwell included reading of Kant's *Kritik of Pure Reason* in German, "*with a determination to make it agree with Sir W. Hamilton.*"



JOHN CLERK MAXWELL
THE FATHER OF JAMES CLERK MAXWELL.

under which his celebrated contributions to *Blackwood's Magazine* were made. Maxwell's interest in the subject of these lectures was deep and lasting, but he had no great respect for the teaching of Wilson.[7]

The liveliness of his mind and the variety of his interests at this period may well be illustrated by extracts from certain of his letters. Thus in 1848, after telling of several mathematical or scientific "props" (propositions) of which he was thinking, he says, "I don't understand how you mug [work] straight on. I suit my muggery to my temper that day. When I am deep I read Xenophon's defence of Σωκ; when not I read Σωκ's witty dialogues. If I do not do this, I always find myself *reading Greek*, that is, reading the words with all their contractions, as a Jew reads Hebrew. I get on very rapidly; but I know nothing about the meaning, and do not even know but that I am really translating." A letter of 1849 begins thus: "Here is the way to dissolve any given historical event in a mythical solution, and then precipitate the seminal ideas in their primitive form. It is from Theodore Parker, an American, and treats of the declaration of American independence. 'The story of the Declaration of Independence is liable to many objections if we examine it *á la mode Strauss.*[8] The Congress was held at a mythical town, whose very name is suspicious—Philadelphia, brotherly love,' " etc.

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[7] In a letter written in 1850 he says "Wilson, after having fully explained his own opinions, has proceeded to those of other great men: Plato, Aristotle, Stoics, Epicureans." "He quarrels with Aristotle's doctrine of the Golden Mean—'a virtue is the mean between two vices'—not properly understanding the saying."

While in the University of Edinburgh Maxwell wrote two scientific papers which Tait,[9] a competent critic, many years later declared to be "valuable," and which were published in the *Transactions* of the Royal Society of Edinburgh. It was probably in regard to one of these that Professor Forbes wrote to Maxwell as follows, in May, 1850: "Professor Kelland, to whom your paper was referred by the Council R. S., reports favourably upon it, but complains of the great obscurity of several parts, owing to the *abrupt transitions* and want of distinction between what is *assumed* and what is *proved* in various passages," etc. This criticism of Maxwell's style in the presentation of his scientific ideas and theories is a valid one. He never acquired pedagogic skill.[10]

It appears that during most of his student life at Edinburgh Maxwell had some thought of following his family tradition and taking to the law. But when, in October, 1850, he entered Cambridge University, he had definitely committed himself to physical science. He at first was in Peterhouse but soon went to Trinity College. He there became a pupil of Hopkins, a famous tutor of the time, and set himself to the long grind of preparation for the Mathematical Tripos. But in all the routine of this training his individuality continually asserted itself. He had, for example, a predilection for graphical, as compared with algebraic, methods of discussion. "Whenever the subject admitted of it he had recourse to diagrams, though the rest might solve the question more easily by a train of analysis." His realization of spatial and physical relations was exceptionally vivid, and in all his scientific discussions, though he was often obliged to put his trust in mathematical formulae incapable of immediate physical interpretation, his constant endeavor was to visualize the problem with which he was dealing. Hopkins said of him, "It is not possible for that man to think incorrectly on physical subjects."

In his diversions also he continued to be unusual. A contemporary of his at Cambridge says: "From 2 to 2:30 A. M. he took his exercise by running along the upper corridor, down the stairs, along the lower corridor, then up the stairs, and so on" till the other inhabitants of the building rose in wrath and threw things at him. Tait, who knew Maxwell at Cambridge, as he had known him years before in the Edinburgh Academy, relates that "He used to go up on the pollard at the bathing-shed, throw himself *flat on his face* in the water, dive and cross, then ascend the pollard on the other side, project himself *flat on his back* in the water. He said it stimulated the circulation!"

A description of his personal appearance as a young man should be given here. "A slight contraction of the chest, and a stature which, although above the average, was not tall enough to carry off the weight of his brow,[11] made him less

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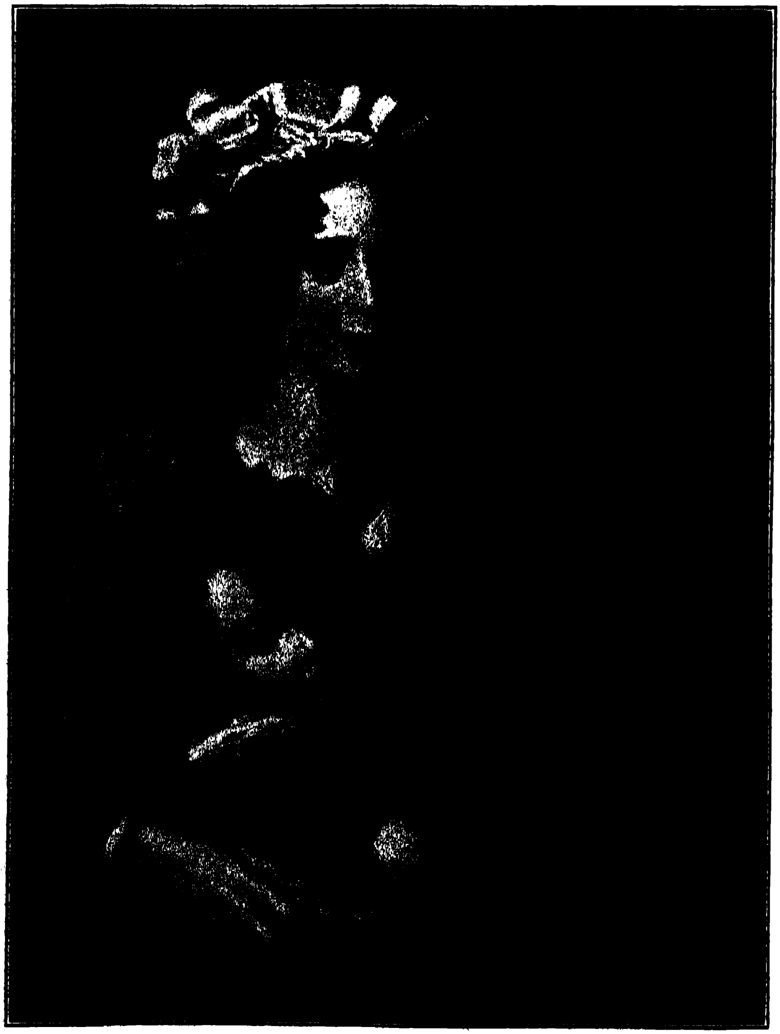
[8] Strauss wrote the "Life of Jesus" in a spirit of historical skepticism. Theodore Parker was a famous Unitarian clergyman of Boston.

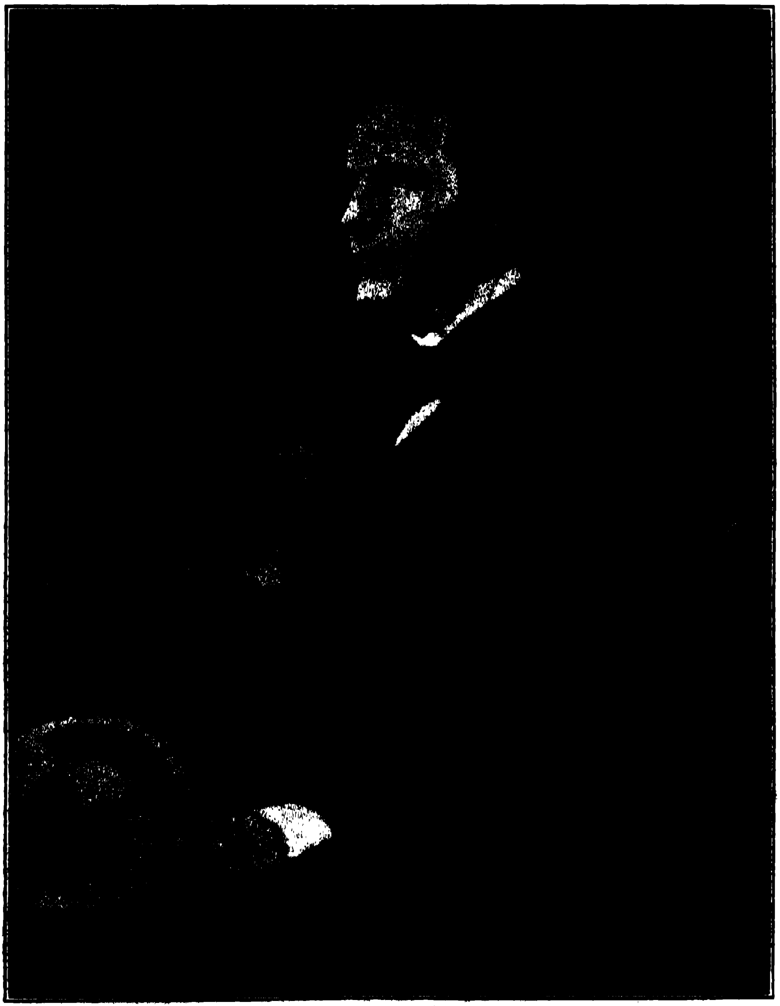
[9] Tait and Maxwell were rival candidates at one time for the professorship of natural philosophy at Edinburgh. Tait won, but the two men remained intimate friends. I once heard Tait recite some humorous lines written by Maxwell satirizing Tyndall's style as a popular science lecturer.

[10] Professor E. L. Nichols, of Cornell, who had studied under Gustav Wiedemann in Germany, told me that Wiedemann, on hearing that some student professed to have read Maxwell's "Electricity and Magnetism" in two months, exclaimed, "Read Maxwell in two months! Maxwell himself couldn't read it in two years."

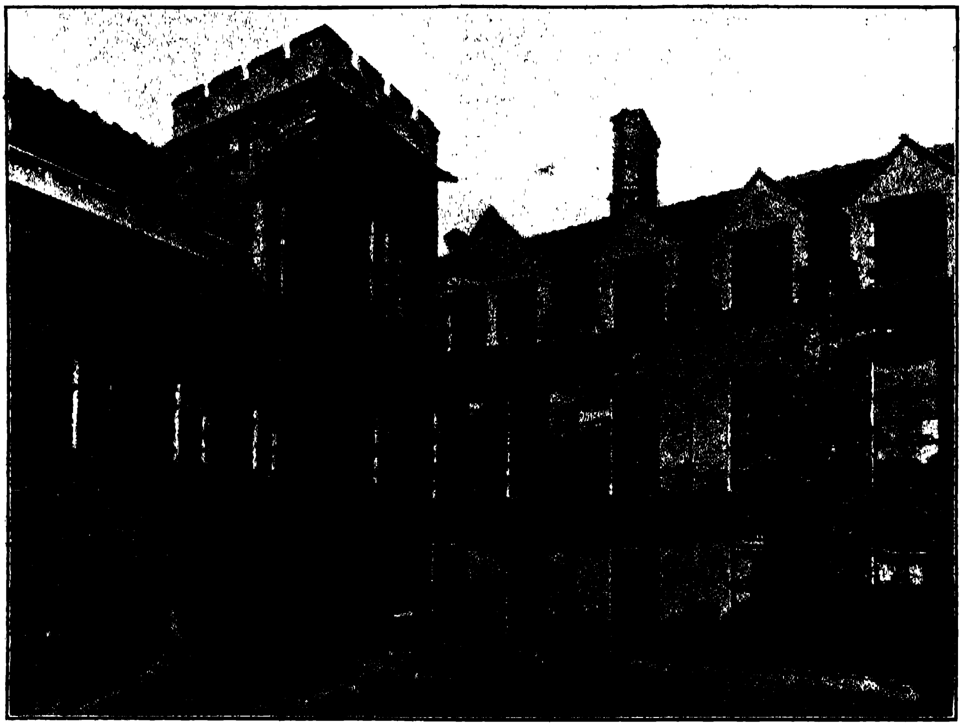
[11] Rowland before assuming the duties of his professorship at Johns Hopkins had by his experimental researches attracted the highly favor-



THE BOY MAXWELL WITH HIS MOTHER



MAXWELL IN HIS YOUTH



THE CAVENDISH LABORATORY

THE PHOTOGRAPH SHOWS THE ORIGINAL WING BUILT BY MAXWELL AND OPENED IN 1874.

handsome standing than sitting.'' But his presence had a charm which made him the center of any circle of his friends. His eyes were dark brown, ''his hair and incipient beard were raven black, with a crisp strength in each particular hair.'' His dress was quiet but showed a nice sense of color, for his eye was both naturally sensitive and highly trained by experimental study.

.Like other college undergraduates Maxwell thought much of religious matters, but with a combination of boldness and reverence somewhat rare. ''Nothing is to be *holy ground* consecrated to Stationary Faith, whether positive or negative. All fallow land is to be ploughed up, and a regular system of rotation followed. All creatures as agents or as patients are to be pressed into the service, which is never to be willingly suspended till nothing more remains to be done; *i.e.*, till A. D. + ∞. The part of the rule which respects self-improvement by means of others is: Never hide anything, be it weed or no, nor seem to wish it hidden.'' He declared that ''Christianity—that is, the religion of the Bible—is the only scheme or form of belief'' which has nothing to hide. He expressly disclaims, however, the proposition that no *Christian* has any *tabooed* spots in his faith.

A bit of literary criticism, emitted when he was twenty years old, is this: ''Do you ever read books written by women about women? I mean fictitious tales, illustrating Moral Anatomy, by disclosing all thought, motives, and secret sins, as if the authoress were a perjured confessor.'' But I must resist

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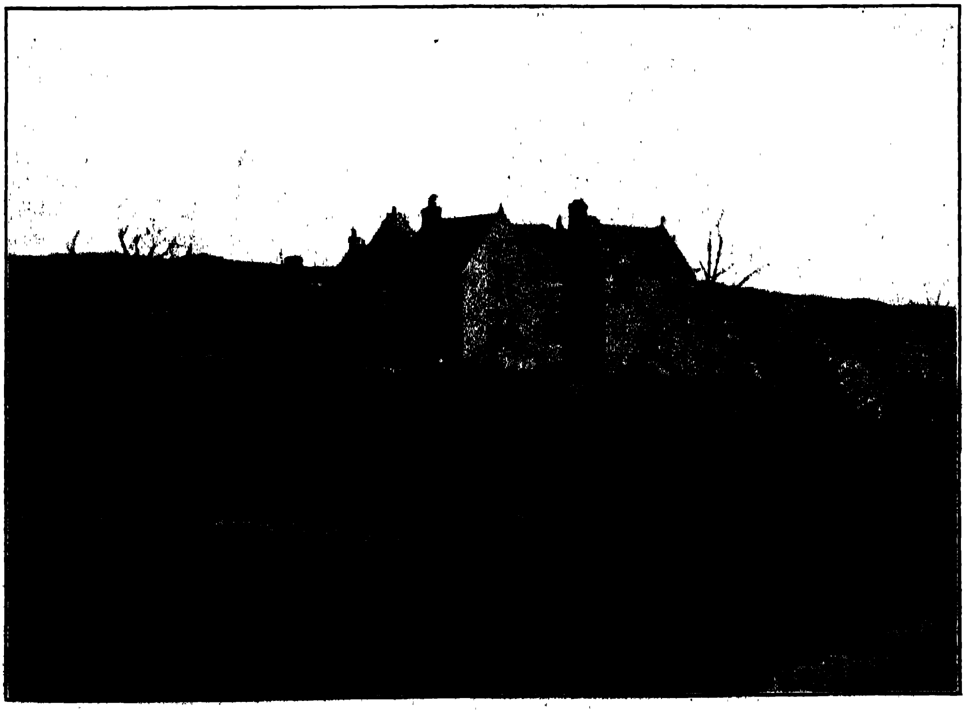
able attention of Maxwell and had visited the latter in England. I once heard him say, speaking of Maxwell, ''I tried on his hat. It was too big for me.''

the temptation to quote further from Maxwell's miscellaneous reflections of this period.

From the Mathematical Tripos of 1854 Maxwell emerged as Second Wrangler, E. J. Routh[12] being the First, or "Senior," wrangler. In the Smith Prize competition, however, a higher test, Maxwell and Routh were "bracketed" together. It has happened more than once, and this is one of the instances, that the Second Wrangler has proved to be in later life a far greater and more important figure than his Senior.

After taking his degree in 1854 Maxwell stayed on at Cambridge for two years, as a Fellow of Trinity College. He did not in this position shirk the routine of teaching and conducting examinations,[13] but he was now able to renew his activities in experimental and theoretical research. He returned to the study of color, a study in part psychological or physiological, and he set himself with great zest to the task of reducing Faraday's conception of "lines of force," electrical or magnetic, to definite mathematical form; for Faraday, though an inspired experimenter and theorist, was no mathematician. The spirit that animated Maxwell in all his labors may be expressed in words of his own, written about this time: "Happy is the man who



GLENLAIR HOUSE, CORSOCK, DALBEATTIE

MAXWELL'S CHILDHOOD AND MUCH OF HIS LATER LIFE WERE SPENT AT GLENLAIR. IT WAS HERE THAT THE GREATER PART OF HIS "ELECTRICITY AND MAGNETISM" WAS WRITTEN. THE PHOTOGRAPH SHOWS THE APPEARANCE OF THE HOUSE AFTER IT WAS ENLARGED BY MAXWELL.

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[12] Routh wrote a number of mathematical works, that were well known, but he was perhaps more famous as a great mathematical "coach" than as an author.

[13] Moreover, he undertook work of a benevolent character quite outside the formal duties of his position, as the following extract from a letter of March, 1856, will show: "I was at the Working College to-day, working at decimal fractions. We are getting up a preparatory school for biggish boys to get up their preliminaries. We are also agitating in favour of early closing of shops."

can recognize in the world of to-day a connected portion of the work of life, and an embodiment of the work of Eternity."

His father died in 1856 at Glenlair, the son being with him and ministering to him at the last. Maxwell, who often expressed his moods, whether grave or gay, in verse, wrote soon after this a poem containing these lines:

> For it is not all a fancy that our lives and theirs are one,
> And we know that all we see is but an endless work begun.
> Part is left in nature's keeping, part has entered into rest;
> Part remains to grow and ripen hidden in some living breast.

An engraving from a painted portrait of the father is here reproduced. It shows a countenance well befitting the father of an eminent son.

For three years, from 1856 to 1859, Maxwell held the "Chair of Natural Philosophy" at Marischal College, Aberdeen. The conditions of his life there were not altogether congenial. He was not a good lecturer for commonplace minds, and Aberdeen, where general public sentiment was in favor of a utilitarian education, did not supply the best of material for his classes. "The spirit of indirectness and paradox . . . would often take possession of him against his will and . . . would land him in 'chaotic statements,' breaking off with some quirk of ironical humor." He declares in one of his letters, "no jokes of any kind are understood here. I have not made one for two months, and if I feel one coming I shall bite my tongue."

But he set himself energetically and not unsuccessfully to his task. In 1857 he writes, "I am at full college work again. A small class with a bad name for stupidity. . . . So I have got into regular ways, and have every man *viva voce'd* once a week, and the whole class examined in writing on Tuesdays, and roundly and sharply abused on Wednesday morning," etc. "Public Opinion here says that what our colleges want is inferior professors, and more of them for the money. Such men, says P. O., would devote their attention more to what would pay."

He volunteered to give lectures for workingmen, however. "Tuesday week I gave a lecture to operatives, etc., on the Eye. I have just been getting cods' and bullocks' eyes, to refresh my memory and practise dissection." Some of the students whom he "sharply abused" entered voluntary classes to continue under his teaching.

But in 1860 the two colleges of Aberdeen, Marischal and King's, were united, and Maxwell's chair was abolished in this fusion. He was then for a short time without a teaching position.

He had, while at Aberdeen, carried on and completed his research on the Rings of Saturn, showing that they must consist of separate small satellites of the planet. Another achievement of his life there was his marriage, in 1858, to Katherine Mary Dewar, daughter of Principal Dewar of Marischal College.

"From this point onward," says his biographer, "the interest of Maxwell's life (save things 'wherewith the stranger intermeddles not') is chiefly concentrated in his scientific career." In the summer of 1860 he was appointed to the professorship of natural philosophy in King's College, London, and he remained in this position, which was a laborious one, till 1865. He thereafter lived in retirement, at Glenlair, till 1871, when he was appointed, without opposition, to the newly established chair of experimental physics in the University of Cambridge, Sir William Thomson having declined to be considered for this position. One of the first to urge Maxwell's acceptance was the Hon. J. W. Strutt (Lord Rayleigh), who was Maxwell's successor in the same chair. Maxwell entered this new undertaking with some misgivings, saying that he had no experience in directing experimental work and intimating that experimental investigation would involve an amount of dull labor that might not be attractive to men of Cambridge education. The world is well aware now how brilliantly Cambridge men have proved their willingness and their ability to go through the drudgery of research to the highest achievements of discovery.

Maxwell's first work in his new position was to design the Cavendish Laboratory and superintend its construction. This building was completed and opened for operation in the spring of 1874, only two years before Rowland began the work of research in his very unpretentious laboratory quarters at Johns Hopkins.

Maxwell's greatest work, his "Electricity and Magnetism," was published in 1873. This book starts with Faraday's conception that electrical and magnetic attractions and repulsions are not direct *actions at a distance* by the electrical or magnetic bodies concerned, but are due to a state of the medium between these bodies. This conception as developed mathematically by Maxwell, with his passion for attaching a concrete physical meaning to all his mathematical expressions, led finally to his electromagnetic theory of light. For several decades light in its objective sense had been explained as a progression of waves, alternations of physical state, in the medium through which it travels. Maxwell reached the conclusion that these progressive alternations are alternations of electrical and of magnetic state in the medium, and showed that, if this theory is true, certain definite numerical relations should hold between quantities measured in the phenomena of electricity and magnetism and quantities measured in the phenomena of light. This may be illustrated as follows: There are two ways of measuring quantities of electricity; one, called the *electrostatic*, is based on the attraction or repulsion of electrically *charged* bodies; the other, called the *electromagnetic*, is based on the *magnetic* action of an electric *current*. Maxwell inferred from his theory that, if the centimeter, the gram and the second are used as the fundamental units of physical measurement, the ratio of the electromagnetic unit to the electrostatic unit of electricity must be equal to the velocity of light, measured in centimeters per second, in a vacuum.

So a little more than half a century ago the leading physicists of the world set themselves to measure, with the greatest accuracy attainable, the "ratio of the units" on the one hand, and the velocity of light on the other hand. America made its contribution to these investigations. Rowland at Baltimore made one of the best determinations of the units ratio. Michelson at Annapolis improved upon all previous measurements of the velocity of light. The more accurate experimental results have become, the more closely has the relation predicted by Maxwell's theory been verified.

It followed, of course, from Maxwell's conception that from any source of rapid and regular alternations of electric discharge equally frequent and regular alternations of electric state travel outward through the surrounding space with the velocity of light. Heinrich Hertz some years after Maxwell's death gave experimental proof of the existence of these traveling alternations, or electromagnetic "waves," detecting them by means of an electric receiving oscillator having the same natural period of vibration as the source. Thus the fundamental principle of the now almost too familiar "radio" action was discovered.

Maxwell died on November 5, 1879, being then 48 years of age. During his last days he said to a friend: "Old chap, I have read up many queer religions: there is nothing like the old thing after all;" and—"I have looked into most philosophical systems, and I have seen that none will work without a God."

A RETROSPECT OF WIRELESS COMMUNICATION[1]

By Sir OLIVER LODGE

As one gets older people seem to think that one's duty is to be a historian of the times during which one has lived. Unfortunately I have not been trained as a historian, and am therefore incompetent to do more than just trade upon my reminiscences, which are liable to be rather one-sided and not to satisfy the conditions for serious and reliable history without prejudice or favoritism. It has been suggested that I speak on the history of wireless telegraphy, under the title "A Retrospect of Wireless Communication."

Looking back, then, over my lifetime, the first item to attract my attention was a paper on "Transient Currents" written by Lord Kelvin (as Sir William Thomson) in 1853, wherein he gave the theory of electric oscillations in a masterly manner, considering that the idea of self-induction was not then born. He knew, however, that an electric charge could be stored in a condenser, after the same fashion as energy is stored in a bent or coiled spring, so that the condenser received and stored up electric energy, which it would subsequently give out when released. That was the first step. He knew, moreover, that the discharge would constitute an electric current, and that every electric current was surrounded by a magnetic field, which would confer upon it something akin to inertia or momentum; so that, like a loaded spring, it would not only recoil when released, but would overshoot the zero mark and reverse of itself, swinging like a loaded pendulum first on one side the zero, then on the other; so that the discharge was not a flow in one direction only, but an oscillating or alternating flow, first in the positive, then in the negative direction. The magnetic field would thus prolong the discharge until the energy was finally wiped out; and the spark, if examined in a rotating mirror (as Feddersen examined it twenty years later) would be seen to be not a single luminosity, which would be drawn out into a uniform band, but would be a succession of luminosities or a beaded band, each band corresponding to a half swing. Kelvin did not attempt this experimental verification, but he went on with the theory.

The elastic recoil or strength of the spring varies inversely with the capacity of the condenser. The smaller the condenser, the stiffer the spring; so that with a large condenser the oscillations would be fairly slow; not really slow, but something comparable to a thousand or a hundred a second, something which could be made to give a musical note, if the capacity were very large. I exhibited this musical note at the Royal Institution many years afterwards in what I called a "whistling spark." The noise of such a spark, instead of being a crack, was a whistle, whose pitch could be brought down to reach the tones of the voice, and indeed lower still. The rate of swing depends not only on the capacity of the condenser; it depends also on the load or inertia of the discharging circuit. It depends on what we now call self-induction, but which then Kelvin spoke of as "the electro-dynamic capacity of the discharger." There was the electrostatic capacity of the charged condenser, and the electrodynamic capacity of its discharging circuit. The two cooperated so as to produce the swing, and the rate of swing depended on both equally, and could be calculated exactly. This theory Sir Richard Glazebrook and I subsequently verified, many years afterwards, in the Cavendish Laboratory, Cambridge, in the nineties of the last century, the result being published in the Stokes Memorial Volume.

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[1] **An Evening Discourse delivered at the Centenary Meeting of the British Association for the Advancement of Science, London, September, 1931.**

The discharger not only had magnetic induction, it also had resistance, and Kelvin's theory showed that if the resistance was above a certain amount, the oscillations would be quenched prematurely. There was a critical resistance at which they would be wiped out, so that the recoil would be dead beat, just returning to zero and staying there. That was the quickest possible method of discharge. But there would then be no oscillations. if the resistance were still greater than that, then the discharge would take longer to reach zero; it would degenerate into a leak, or at first into a sort of intermittent current, returning towards zero spasmodically in jerks all in the same direction.

Now a flash of lightning is the discharge of a condenser, that is, the discharge of a store of electricity in the cloud; and Dr. Simpson, the eminent meteorologist, has shown that the resistance to a flash of lightning usually exceeds the critical value which would make the discharge dead beat, and still more exceeds the value which would permit it to be oscillatory, and in fact makes it intermittent; so that the lightning, if photographed, is seen to be a series of spits, succeeding one another very rapidly, and giving a jerky current all in one direction. Lord Kelvin's theory of 1853 provided not only for the oscillatory discharge and its dead beat condition, but also for the leak likewise. If the resistance was enormous then the charge of the condenser would simply leak away, the law of discharge being then exactly like that of a hot body cooling. For heat has no inertia, and therefore has no tendency to make oscillations. The hotter the body the more rapid the leak, that is to say, the cooling process: and the return to zero is asymptotic, that is to say, the potential falls down an exponential or logarithmic curve, getting slower and slower as it comes nearer zero, and gradually approaching it, taking theoretically an infinite time actually to attain it. That theory of Lord Kelvin's about electric oscillations or what he called transient currents dominated for me the nineteenth century, and was illustrated by innumerable experiments, at different times in the century. In the year 1889 I lectured on the Leyden jar at the Royal Institution, and showed many of these effects.

But we did not know then that there was another reason for reducing the time during which the charge continued to oscillate. It was killed not only by the resistance of the circuit, but by a certain proportion of energy radiated away into space. We did not know that there was any such radiation, nor did Lord Kelvin. We knew, or might have thought, that such radiation was possible, by the analogy of a tuning-fork. A struck or excited tuning-fork gives sound vibrations which die out at a certain rate. They die out partly because of the resistance of the steel of the fork, and partly, indeed chiefly, if the fork is mounted on a sound-board, by reason of the radiation which is thrown out into the air. A genius might have surmised that, as the tuning-fork vibrates in air, so the discharge of a Leyden jar or other condenser, being a vibration in the ether, might possibly carve the ether into waves and emit energy in that way. That is what happens, but no one suspected it for a long time; they did not know that the conditions for ether waves would be satisfied by an electric discharge. We had no sense for such waves, and could not tell that they were being emitted, even when we made the experiment. We were in the condition of a deaf person striking a tuning-fork or a bell. If you could not hear the sound emitted by the fork you would not know that there was any; and you would certainly not experiment on the waves, measure their wave-length, and utilize them for purposes of communication.

The first to show that an electric discharge would generate such waves, that is to say that an alternating or oscillating current would lose a certain fraction of energy to the ether at every swing, was George Francis FitzGerald, who in the year 1880 examined the question mathematically, communicating it to Section A of the British Association; and in 1883 followed it up with a further communication, in which he calculated the actual amount of energy lost in a second by a given condenser and self-induction. This was a great feat, and I will write FitzGerald's result on the board, for it is used to this day. It showed that a short wave oscillator radiated much more vigorously than one that vibrated slower; that the radiation power, in fact, depended on the fourth power of the frequency, other things being equal.

The radiating power of a current i oscillating in a time T in a circle of area πa^2 is

$$\frac{8\mu\pi^4}{3T^4c^3}\cdot(\pi a^2 i_0)^2$$

which simplifies to this in terms of wave-length

$$8\times 10^{12}\frac{(\pi a^2 i)^2}{\lambda^4}.$$

His theory shows why an ordinary alternating dynamo does not radiate appreciably; it does radiate, like every alternating current, but if its frequency is comparable to 100 a second the amount of energy lost is next to nothing. To get at anything like efficient radiation you must have an alternating current of a million a second or more; and if you could only work up the oscillations till they were five hundred-million-million a second (which sounds preposterous) then you would have the means of detecting them. They would be sufficiently rapid than to excite our sense-organ, the eye, and give us the sensation of a strong yellow light; for what we call light is just an etheral vibration excited by an electric oscillation of this extravagant frequency.

Still we didn't know how to produce these oscillations, and still less how to detect them. FitzGerald virtually said that the oscillations were there whenever a Leyden jar discharged. On what ground was he able to make that assertion? How did he know that an electrical oscillation would generate ether waves just as a tuning-fork generates sound waves? He only knew that on the strength of the work of a great genius, James Clerk Maxwell, who in 1865 communicated papers to the Royal Society and to the British Association a year or two later, giving the result of his mathematical theory of Faraday's views on electromagnetic phenomena. Maxwell's equations expressing electric and magnetic relations were, and still are, of the utmost importance. They are not expressed in the simplest possible form, but they are remarkably complete. Simplification came later. But as a foundation for all the work that followed during the century, Maxwell's equations are the basis, and shine with undiminished brightness down to the present day.

This leads me to make a digression on the work and methods of mathematical physicists. Their plan in studying any phenomenon is to bethink themselves of what is the fundamental fact or process underlying it. They express that process in what to them is the simple form of an equation, and having written down equations appropriate to each aspect of the phenomenon, they proceed to combine these equations according to certain rules, the rules of pure mathematics, and deduce the consequences. It is not a process that comes naturally to ordinary people; indeed, they find a difficulty in following it. When they do follow it, they are apt to be lost in admiration, first for the insight which enabled them to express the fundamental laws in that tractable form, and next for the skill with which the forms have been manipulated, so that results could be interpreted which might subsequently be put to the test of experiment and thus verified. Verification is always necessary because, though the theory may be accurate as far as it goes, it never goes all the way, and it may fail in not going far enough. A complete theory of any phenomenon would have to take all the universe into account, but no one aims at such a complete theory: they take the most essential features of what is happening and ignore the rest. It takes some genius to perceive what the most essential features are, and to judge whether the other things may be ignored or not. When the theory fails to be verified in practice it means either that some error has been made in the calculation, or, more probably, that something has been ignored which ought not to have been ignored. Thus, for instance, to take a trivial example:

Professor Tait, the great mathematician of Edinburgh, calculated the trajectory of a golf ball, taking into account a good number of the causes governing it—the impact of the head of the club, the inertia and elasticity of the ball, the resistance of the air, the force of gravity, and so on. His first theory gave him a maximum range which no one, however skilled, could hope to exceed. Then, as is well known, his son, Lieutenant Tait, a skilled golfer, exceeded it. What did Tait do? He didn't abandon the theory; he perceived that something more must be taken into account. What he had ignored as unimportant was the spin on the ball. A ball when struck except in a line exactly through its center, will not only move forward but will be set spinning. Every one knows the effect of spin on a billiard ball. A skilled player purposely puts it on by the way he strikes the ball; it will then rebound from the cushion or from another ball in a way different from what it would if it were not spinning. A spinning ball might move in a curved line. But then a billiard ball is rolling on a table, a golf ball is not. Still, it may be rolling on the air through which it is moving. Tait perceived that the spin must not be ignored, but must be fully taken into account. He remodelled his theory, writing down some more equations to take the spin energy into consideration. He thus made a more complete theory, which led to curious results, most of which have now been verified by experiment. The practice and the theory agreed to a sufficient approximation, and the theory is then said to be complete. I am only taking this as a typical instance of the way in which mathematics is applied to physics, to secure in this instance a trivial result. Of course, a mathematician might have taken the whole into account at first, and then the theory would have been complete from the beginning and there would have been nothing to correct afterwards.

That was the kind of way in which Newton proceeded. When he gave his theory of astronomy based upon gravitation he at first took the heavenly bodies, first as particles then as spheres, and thus arrived at a first approximation to the theory of their motions. But he knew that the earth itself could not be a sphere, because it was spinning on its axis; it must be an oblate spheroid. That had never been observed, but Newton predicted that it was so, and proceeded to trace the remote consequences of the shape of the earth. He found that it accounted for the precession of the Equinoxes, which had been known as an empirical fact to the ancients. Copernicus had said that precession must represent a conical motion of the earth's axis; but no one knew any cause for such a conical motion. Newton with his extraordinary genius perceived that a conical motion, very slow and taking thousands of years for its revolution, would be the exact result following from the pull of gravitation on an oblate spheroid. A spheroid would not act as if all its mass were concentrated at its center; it would be more complicated than that. He was not deterred by the complications, but worked them out and completed his theory.

Another thing that had been ignored in the first view of astronomy was the size and plasticity of the bodies; they were treated as particles or rigid bodies, and this gave the first approximation. But obviously the earth is not a particle but a body of considerable size, so that some parts of it are appreciably nearer the sun or the moon than are the parts at the Antipodes. Newton took the size into account, and thus was able to show that anything yielding or mobile on the surface of the earth, like the ocean, would have a motion distinct from the rest of the earth to a slight extent, and would go through an oscillation periodically. This oscillation of the water on the earth he perceived would account for a phenomenon that had been known from antiquity, but had never been explained, namely, the tides. He completed his theory by working out the tides in all their main detail, leaving it to others to show how great an effect tidal phenomena had had on the evolution of the universe.

This has been recently extended and applied by Sir James Jeans to the production of a solar system. He has shown mathematically that if a visiting sun entered our neighborhood, coming within a reasonable distance of our sun, it would excite tides upon the sun, which might increase to such an extent as to throw out an explosion or protuberance. The history of this he followed up, and showed that it would presently aggregate into round bodies revolving round the earth, the bigger ones in the middle of the protuberance, the smaller ones at either end, and thus provide the sun with a system of planets, on one of which we happen to live. Well, that is a further development of tidal theory, taking into account all the possibilities, or at any rate such of them as a genius is able to consider relative, and giving an idea which at present seems likely to hold against adverse criticism about the origin or creation of the earth and other planets. This again is a digression, and I do not see how the theory is to be verified by experiment. All this development could not be done by one man; the genius who made it possible is Isaac Newton. The further developments of his theory were left to posterity.

So it was also with Clerk Maxwell. He wrote down some equations which expressed what Faraday had long brooded over as the electric field, regarding it as distinct from matter and existing in the ether of space around the charged body. He also wrote down another set of equations expressing the magnetic field surrounding a current. And then he began to combine these, so as to see what an electromagnetic field would be like, that is to say, a field which combined an electric displacement with a magnetic whirl. Do not suppose that this was an easy thing to do, but Maxwell did it, and found (possibly to his surprise, possibly to a satisfaction of his instinct in that direction), that the equation he now got, a differential equation of the second order, was one that was familiar to him and to other mathematicians, namely, the equation to a wave; that is, a disturbance periodic in space and time, which advanced through space at a certain rate. This rate was expressed by an electric and a magnetic constant of the ether, which were immeasurable; no one knows to this day how to measure them. But the rate of propagation of the electromagnetic wave did not require the separate constants to be measured, nor need we know what each was; only their product entered into the expression. Experiments made abroad, in Germany, had indicated a way of determining this product; Maxwell bethought himself of another method, and proceeded to put it into practice in the laboratory of King's College, London, where he was then a professor. He performed the experiment, worked out the result, and obtained a speed for the transmission of electromagnetic waves very close to the velocity of light. It looked as if ether waves were just what we had been using all along for optical experiments and for arousing our sense of vision. We had been discussing whether ether waves were possible; they were familiar, only we didn't know they were electromagnetic.

All manner of theories of light had been tried in the early part of the nineteenth century—very ingenious theories, depicting the ether as a kind of elastic solid or jelly, in which the vibrations travelled at an immense pace. But none of these theories had been satisfactory. They covered the ground to a great extent, but they failed sooner or later. There were things we could not account for by any elastic solid theory. But Maxwell's theory that light was not mechanical but was an electromagnetic phenomenon, that its laws were ascertainable by electric and magnetic experiments, was a tremendous eye-opener. His book was published in 1873. The president of Section A of the British Association called attention to it, and we young people were all agog to understand this theory better, and if possible to verify it by actually producing ether waves electromagnetically. That was what set FitzGerald to work, and I have given you an indication of his results.

I also set to work experimentally, and tried to produce the waves by the discharge of Leyden jars. No doubt I did produce them—that was easy enough; the thing was to detect them. The eye is useless for waves measured in meters; it can only deal with the excessively rapid vibrations that constitute light. We needed what Lord Kelvin called "an electric eye." We worked mainly with closed condensers—that is to say, things of which the opposite plates were near together—and tried to see if there was any sign of waves running along wires which were attached to such discharging condensers. In 1887 or '88 I got the evidence in the form of nodes and loops characteristic of ether waves, reflected back on themselves at the terminal of the wire. But Heinrich Hertz in Germany, though not himself seeking to verify Maxwell's theory, which had not attracted much attention on the Continent, but making experiments on the way in which electric force streamed out from a discharging conductor, arrived at a sensational result. He did not work with closed circuits. He took two plates, like the two coats of a Leyden jar, separated from one another as far as possible, and joined by a wire: in fact, he made what we now call a Hertz vibrator. It can hardly be called a condenser, but still it has capacity and self-induction, that is, the two ingredients necessary for an oscillation, and when the two surfaces were charged oppositely and sparked into one another, oscillations were set up, and waves were generated, as FitzGerald had perceived they would be. They were generated in space, however, because the electric field was spread out in space as well as the magnetic. They had such energy, these waves, that when they fell upon a conductor they caused it to emit little sparks. Such a thing as that we experimenters had not imagined possible. We had never thought that a luminous field would be strong enough to excite sparks when absorbed. FitzGerald might have thought of it if he had interpreted his expression in terms of energy numerically. He had not done that, none of us had done that, but he perceived the strength and beauty of Hertz's result, and in 1888, at the British Association meeting in Bath, he called the world's attention to the fact that Maxwell's electromagnetic waves had at last been produced; not only produced, but detected, and detected by their extraordinary amount of energy sufficient to emit sparks.

After that, progress was rapid. Hertz's discovery was first understood and made notorious in this country. It never caught the ear of the public, it was not taken up by the newspapers, but it could not fail to arouse attention through the whole of the scientific world. Hertz showed that Maxwell's theory would account for his radiation in every detail; he made a map of the process by which the radiation was generated in an electric oscillator, that is, he mapped out the lines of force during every phase of an oscillation—the beginning, the quarter of an oscillation, half of an oscillation, three quarters, the complete—and these maps of lines of force were published in *Nature* when I translated his paper into that journal in February, 1889. See Vol. 39, p. 451. They could be shown in action on a kinematograph.

The only method of detecting them at first was the scintillae which they produced. I found another means of detecting them by two knobs in loose contact in the circuit of a battery and galvanometer, or again in any form of loose joint and a telephone. This was the coherer principle, subsequently made more practicable by Branly in France, who found that the resistance of the metal coating smeared on paper, or a tube of iron filings, fell suddenly when a spark was taken in its neighborhood.

Now the era of scientific discovery was nearly complete. The rest was what happens when any application is made of science on an extensive scale. A multitude of ingenious inventors combined their ingenuity and experience to apply the process on an engineering scale and to improve it out of all recognition. In 1894, I showed that Hertz's waves, combined with a Branly detector, could be used for sending and receiving messages in the Morse code by the emission and detection of waves from an electric oscillator, a signal or series of waves being emitted and detected at every spark.

About the same time, or soon after, Professor Righi took the matter up and, in Italy, Senatore Marconi began applying the same process privately in his father's garden. In 1896, he came over to this country with an introduction to Sir William Preece, chief engineer to the Post Office, aroused his interest and enthusiasm for this method of signalling, and secured his cooperation. No doubt he encountered many difficulties, not only scientific and engineering but also financial; but he persevered and won through, and to him must be attributed the great success of wireless telegraphy. Before his patent was published, I perceived that something more would be wanted; that as stations multiplied there would have to be selection, and that tuning was necessary, not only to give selection, but also to give sufficient sensitiveness. One station could be worked upon its own wave-length, by a receiver with capacity and self-induction attuned to that rate of vibration. Such a receiver would be very sensitive to one length of wave, and would exclude all other waves. This was patented in 1897, and was regarded afterwards by the courts as the bottom patent for tuning; it was extended by Lord Parker for a total period of 21 years, and for the last seven years was purchased by the Marconi Company. Other improvements were made, too numerous to go into. Marconi's special kind of radiator was an elevated aerial connected through a spark gap to the earth. He was thus able to reach great distances, because the waves oscillated in a vertical plane, so that the electrical vibrations were not wiped out, as they might have been if they had been horizontal, by the resistance of the earth and the sea-water over which they went.

Then came another striking discovery, which must be credited to Mr. Marconi working with unexampled energy on an extensive scale. He arranged for a large sending station in Cornwall, and travelled across to America to see if he could hear the signals in Newfoundland. I imagine that the scientific world must have been against him in this enterprise, since the waves could not penetrate the substance of the earth, and could not apparently travel round it to reach America. They would apparently travel in straight lines. But enterprise was rewarded, and the signals were heard: only three dots signifying the letter S; that was the arranged thing to be sent. It was enough: it began the series of transatlantic communication. There was something in the earth's atmosphere, an upper layer postulated by Heaviside, as an effect due to the solar radiation in ionizing the upper air, which caused the upper air to act as a kind of mirror, and make the whole earth into a whispering-gallery, so that waves impinging on the layer no longer went straight, but curved round until they reached the Antipodes; so that waves sent out in this country could be heard ultimately all over the surface of the earth. When I say "heard" the waves could not be heard; they make no impression on our senses until they are received by a suitable and attuned apparatus, when the high frequency electrical disturbance is transmuted into the low frequency mechanical disturbance that we call sound. No sound travels from the distant station to the receiver, nothing but ether waves which travel with the velocity of light; so that they reach the whole earth simultaneously. But at the receiving station they are converted into sound energy, and then operate on a telephone.

So far all signalling had been of a spasmodic or discontinuous character. A short series of waves was emitted by each spark, and it was by a succession of sparks that messages were sent. There was no continuity in the waves themselves. But many people perceived that it would be an improvement if, instead of generating a jerky series of independent trains of waves, we could generate a continuous wave at the sending station, so that the signals might consist of modifications or modulations in its amplitude, which modulations might recur with a frequency of their own after the fashion of group waves. To use an acoustic analogy, the method hitherto in vogue had been analogous to signalling by strokes on a bell; whereas what was aimed at was to get something more like organ notes, which would be continuous except when modulated by some kind of keyboard.

So far as I know, the first method of achieving this was the outcome of an experiment by Duddell with an electric arc as part of a tuned circuit. The circuit had a capacity and self-induction in series with the arc. The arc acted very like the blast of air on the lip of an organ pipe, giving an irregular flutter or disturbance which might be made periodic by a suitable resonant cavity, the resonant cavity or organ pipe itself being represented in the electrical case by the self-induction and capacity, that is, by the inertia and elasticity of the circuit. So long as the circuit was not interfered with, the note emitted was of a uniform tone; but by means of a key the self-induction or capacity could be varied, and thus the note emitted could be changed. In that way with a few keys Duddell was able to carve the continuous wave into an imitation of the national anthem or any other well-known tune. Duddell's arc, however, only responded to slow vibrations or long waves; a big self-induction and capacity were necessary, and the arrangement was not applicable to the extremely high frequency needed for an effective sending station.

Poulsen, however, improved the arc by immersing it in hydrogen gas under various pressures, until he had got an arc of really high frequency, which he patented in 1903, and thereafter used it for generating continuous waves of a frequency such as would generate radiation.

Then came the question of receiving such waves. The thermionic valve was known as a rectifier, that is to say, it transmitted a current in only one direction, because it conveyed the current by the flight of electrons in a partial vacuum. Every vacuum tube acts as a rectifier, since it only transmits the current in one direction. Fleming perceived that this rectifying action of a partial vacuum could be employed as a detector of ether waves, and so patented the vacuum valve as a detector in 1904. It was used at first for the discontinuous system of spark signalling. The unrectified pulses were far too rapid to affect a galvanometer, or even a telephone; but when rectified, so that only half of each wave was employed, the pulses could act in groups, and each group could cause a sound in the telephone, so that if the groups followed one another in regular succession they could cause a musical note whose pitch depended on the frequency with which the groups succeeded one another.

To get the groups out of the continuous wave Fessenden devised the heterodyning system of receiving, that is to say, he superposed on the received wave another wave of nearly the same frequency, so that it would beat with the first. The actual vibrations of neither wave can be heard, but the beats, which represent the difference of the frequencies, are much slower than the generating waves, and therefore come within the range of audition. The beats may, for instance, succeed one another at a thousand a second, whereas the generating waves had a frequency of a million. By this combined plan of heterodyning and rectifying a modulated continuous wave to be received, no matter how complex the modulations were, it was possible to superpose upon a carrier wave the modulations of a human voice applied to it by a microphone and then these complicated modulations could be received at the distant station, and the tones of voice reproduced. This was the beginning of wireless telephony, which depends upon emitting and receiving the modulations of a continuous wave.

But the amount of energy received at a distant station was small, and accordingly the voice was very feeble. But De Forest introduced a grid into the valve, giving it three electrodes instead of two, and supplied the valve with a local high tension battery, so that a stream of electrons travel from cathode to anode, passing the grid on the way. If the grid was not supplied with the pulsations of the received wave it would sometimes be positive and sometimes negative in potential. When it was positive it would help the electrons up on their way; when it was negative it would repel them and beat them down. Thus it stood in the middle of the traffic like a policeman and regulated it, sometimes helping it on, sometimes stopping it. But the energy of the traffic does not depend on the policeman; he merely regulates it. So it is with the grid. The energy of the triode valve is determined by the local battery, and may have any value you please. But the regulation of it, that is the modulation on which signals and voice depend, are determined by the grid, which carves the otherwise continuous traffic into an intermittent stream, in accordance with the fluctuating potential of the grid. So that, although the grid is supplied with very small power, its influence in regulating the traffic is considerable; and the power derived from the valve is thereby regulated in accordance with the received wave, but has a power depending only on the local battery. It acts, in fact, as a relay, putting fresh energy into the disturbance, but not otherwise interfering with it. The electrons are so docile that they follow every fluctuation with precision, so that every feature or tone of the voice is accurately reproduced, however much it be magnified. That is the beauty of the three-electrode valve; it magnifies without appreciable distortion. There is no distortion in the ether of space, and accordingly the feeble fluctuations imposed on the wave by the voice at the sending station can travel any distance across space without injury, except that they become weaker; and then these residual fluctuations can be magnified up in amount, still retaining their features, until they are capable of actuating a loud-speaker and being heard all over a hall. If the magnification is being pressed to extremes, a little distortion does enter in, not because the ether has any deleterious effect, but because a certain amount of matter is introduced into the circuit, which has the usual imperfections associated with matter; and thus, though the magnification that could be used is very great, it is not infinite.

Next it was found that the valve could also be used for generating continuous waves, at the same time enhancing their power enormously; so that a talker at the microphone could have the modulations of his speech magnified till they were represented by great electrical energy, which then emerged as ether waves from the aerial, and travelled to a distance, where some trace of them was picked up by another aerial, again magnified, rectified and transmitted to the ear. In that way it became feasible to transmit speech or music to great distances. This was in 1913.

Four years later the remarkable property of quartz was utilized. A crystal of quartz, if squeezed, becomes positive at one end and negative at the other, this being the kind of electrification produced by pressure applied to the peculiar structure of the crystal. This effect is reversible, so that when it is electrified it constricts as if squeezed. Quartz thus furnished an intermediary between mechanical and electrical vibrations. The pressure applied to quartz was mechanical; the electric effect resulting was etherial. The two being reversible, there was a possibility of transmuting an ether wave into a sound wave, or *vice versa.* Quartz could be used either for sending or transmitting. A thin plate of quartz would have a high rate of mechanical vibration in the longitudinal direction. An electrical vibration of the same frequency applied to it would call out this very high frequency sound vibration. It could not be heard, it would be supersonic, but it could produce various effects. These effects have been studied of late years by R. W. Wood, of Baltimore, and other people. The facts are astonishing, and have introduced a fresh department into science called supersonics.

Eccles, however, proceeded to use the vibrations of quartz as a transmitter for electrical waves of steady frequency. He regulated the frequency by a tuning-fork, adjusted once for all to the frequency desired. He then caused the fork to operate on a piece of quartz so as to generate electrical vibrations of the same frequency. These could then be magnified up, transmitted to the aerials of the Rugby station, and so send out waves of enormous power all over the earth, with a precision of tuning hitherto unequalled, so that an operator at a distant receiving station with an accurately tuned receiver could do anything he liked with them.

Broadcasting on a large scale now became possible. In 1920 it was initiated in the United States, and in October, 1922, the British Broadcasting Company started its career in this country. Later it became a government institution, the British Broadcasting Corporation, and, under the management of Sir John Reith throughout, made itself responsible for transmitting speech and music from a number of stations on different wavelengths to all the houses in the British Isles (and far outside them) who would pay for a license.

CHILDHOOD IN THE MACHINE AGE

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OUR country's most precious natural resources are not best represented in subterranean acres of coal beneath the soil of Pennsylvania or Virginia; nor in the fountains of oil that spurt incessantly from the great gushers of the southwest; nor yet in the glittering minerals that lie deep in the heart of the Rockies; nor in the iron-ribbed hills washed by the waters of Lake Superior. Significant as all this natural wealth is to the progress of an industrial era and a machine age, it shrinks astonishingly when weighed in the balance with that greatest of all natural resources—the childhood of the nation.

For fifty years and more—indeed, ever since the later decades of the last century, when the talons of industrialism began first to bury themselves in the brawn of our human society—we have been witnessing the evolution of an age wholly unlike any previous condition that the race has ever achieved. We have beheld the tapping and the exploitation of the vast mineral and natural treasure of America as men, aflame with the passion to create and enjoy new wealth, have turned their genius into these channels. We have seen the development of factories, industrial establishments and commercial agencies to devise, manufacture and sell myriads of new kinds of merchandise. We have witnessed the construction of a labyrinthine distribution system to transport to the remotest corners of the nation new products and new commodities. We have witnessed the steady withdrawal of the population from the villages and the open country, and its concentration in great urban centers in order that human pawns might find place as cogs in the grinding gears of the industrial machine. Increasingly, we have applied ourselves to the building of a novel civilization reared upon the sure and unfailing foundation of coal, iron and, latterly, oil.

Meantime, what of that other great natural resource—childhood? Have we been as eager to develop all its inherent possibilities as we have those of steel, or of electricity? Have we improved and bettered its status commensurately with the improvement that we have brought about in fifty years, say, in the smelting of iron, or in the perfecting of the internal-combustion engine? Oh, yes, we have builded school buildings architecturally and intrinsically second to none in any country on the globe. We have levied and expended for the equipment and maintenance of them more dollars out of the public tax money than for any other enterprise of government. We have trained teachers, employed experts to supervise them, and provided pensions for them after their period of usefulness is ended. As the changing demands of our culture and civilization have made imperative a more elaborate school, we have introduced a whole galaxy of new subjects into the curriculum. We have established a system of secondary education for the children of the masses which is unique in America, and with which there is nothing even remotely comparable elsewhere on the face of the earth. We have compelled all children to attend the lower schools throughout the pre-adolescent years, and have urged and made so attractive attendance in the secondary school, during the early adolescent years, that enrolment in our high schools has multiplied itself faster than we could provide the housing. Side by side with our great public education service, we have planned and brought into existence health centers, medical inspection, nursing and dental service, playgrounds, athletic fields, gymnasiums, scouting activities, and a score of other agencies designed to minister to the needs of the physical growth and welfare of a junior population which at the present time numbers no less than 45 millions. Oh, yes! We have taken good care of childhood! We have kyanized it, preserved it, conserved it! Look at all the money we are pouring into education and training!

But have we?

Here are the facts:

Of the 45,000,000 children in America under 18 years of age:

6,000,000 are undernourished! These are they who, as the years pass, will fall prey to all manner of infectious diseases, including tuberculosis, because they will lack the physical stamina to resist disease. These are they who will contribute most liberally to swell the ranks of postponable deaths—about 500,000 annually at present, or 42 per cent. of all deaths—with a gross annual economic loss to society of more than a billion and a quarter of dollars.

1,000,000 have damaged hearts! Ten years ago, and more, the mortality statistics from the registration area showed tuberculosis—the great white plague—to be the chief cause of death in the United States. Today, heart disease stands at the head of the list! These 1,000,000 children, with hearts damaged by the childhood diseases and their after-effects, are they who will, as the years pass, be reported as those who "died suddenly" of heart disease, for it is a well-known though little appreciated medical fact that the great cause of heart disease and fatality in middle life is to be found in hearts that have been damaged in the early childhood years.

1,000,000 have defects of speech! These are they who will find themselves sharply limited in their vocational prospects, whose personalities will be poisoned from the earliest schoolroom years, and who are being doomed to a lifetime of rebellion, suspicion, and not infrequently of moral obtuseness and obliquity.

675,000 are recognized and branded in the community as "problem children." These are they who in childhood are maladjusted to their homes, to their mates, or to their general milieu. They include the timid, the lazy, the disobedient, the dishonest, the temperamental, the emotionally uncontrolled, the "bad" children, the incorrigible, the sex-dominated, and a host of others who, unless their social, personal, or character abnormalities are corrected, will, as the years pass, grow up to fill our almshouses and jails and prisons and asylums, or, escaping that fate, will swell the ranks of the "queer," the neurotic, the unstable, the profligate, and the prostitute.

500,000 are dependent! These are they who, denied the right of every child to a home and parents, must be reared in orphanages, foster homes and institutions. As the years pass, some of these will pull themselves up by their boot-straps and will climb into positions of honor and respect in the community. Others of them will be confirmed in habits and attitudes of waywardness, sullenness, introversion, moroseness, inferiority, anti-socialism and worse.

450,000 are mentally retarded. This is a very conservative estimate, representing one per cent. of the total junior population. The mentally retarded include all grades and degrees of the backward, from the "repeater" in the schools to the lowest-grade idiot in the institution. Subjected to the same educational regimen as normal children, the mentally deficient at best only waste their time in the schoolroom, and at worst develop all manner of maladjustments and grow up to be social and economic liabilities in the community.

382,000 are tubercular. These are they who are in the fell grip of what turns out to be in more cases than not a losing struggle with the great white plague. While our educational measures have brought about a steady reduction in incidence of this dread disease among adults, they have been less successful in the younger groups. Tuberculosis kills as many school children today as it did two generations ago. It is the fourth most common cause of mortality during infancy, and in the 10–14-year period it ranks first. 150,000 people in the United States have been crippled by tuberculosis of the bone alone.

842,000 are hard of hearing, and 18,000 are totally deaf! In the life game, these are they who by the very nature of their handicap must be denied admittance into many vocations, will be restricted sharply in their social contacts, and will be inevitably prevented from developing some of the fundamental traits of character and of personality. Very commonly they will develop quite decidedly negative ones.

800,000 are crippled! Infantile paralysis, tuberculosis and other diseases are taking a toll in leg and limb that shows no evidence of diminution. In fact, the ratio of crippled children to the whole population remains about the same from year to year. This is one of the tragedies of our age.

200,000 are delinquent! This includes only those who pass through our juvenile courts in a single year, and takes no account of the far greater number of delinquencies handled by the police, nor of unapprehended delinquencies. In 1927, about 1 per cent. of the children of juvenile court age in the United States, for the area in which statistics were available, came before the courts as delinquents. These are they who in the years to come will furnish most to our national quota of racketeers, criminals, scoff-laws, prostitutes, gangsters, hold-up men, *et al.*

And so the drab facts run! They tell a disconcerting tale relative to American childhood. Ten million strong, the great army of the underprivileged, the defective and the delinquent, are hammering at the very gates of the citadel of our civilization. They are demanding those inalienable rights that must in the future be vouchsafed in increasing measure to all children: health, the correction of their deficiencies, protection from the by-product evils incident to our social and industrial organization, and the establishing of such an intelligent and far-seeing program of prevention touching every phase of child welfare as may be worthy of a great and enlightened people.

With the purpose of setting in motion such a program of conservation in the realm of childhood, President Hoover, somewhat more than a year ago, took the first steps in creating the White House Conference on Child Health and Protection, which convened in the city of Washington, November 19th to 22nd, 1930. The President was cogently aware of the multiplicity of problems of child life and training that a changing society has brought to the forefront. In a machine age and in an industrial era wherein human life has been literally transformed into new terms and new values, it was apparent to him that there must be a huge body of factual material with reference to child hygiene, child guidance, home training, dependency, delinquency, and the like which, if assembled by experts, could be turned to valuable account in the shaping of a wholly new science and a new gospel of child welfare and training. It was apparent also that the rank and file of people have obviously not kept pace in the rearing and training of children with the scientific developments in the general field of child health and welfare, and that there was need of a national survey to focus public attention upon the newer knowledge.

Taking its origin from a small group of well-known men and women to whom the President first made known his wishes, the White House Conference on Child Health and Protection was expanded to include some 1,200 experts in related fields of child welfare. These workers were headed by the President's planning committee, under the chairmanship of the Honorable Ray Lyman Wilbur, Secretary of the Interior, and the vice-chairmanship of the Honorable James J. Davis, then Secretary of Labor. Altogether, a total of some 170 different committees and subcommittees devoted approximately a twelvemonth to research and investigation in preparation for the conference. These 170 committees represented seventeen divisions, as follows: Three in medical service; three in public health service; seven in education and training; and four in the handicapped. Each committee and subcommittee was under the immediate chairmanship of a nationally prominent expert in the field represented by the specific activities of the group. There is no phase of child life which was not covered by some or another of these professional groups. Men and women all over the United

States and the dependencies gave willingly and gladly of their time and skill in the name of childhood. There was no congressional appropriation behind the project; there was no political engineering nor control. Every member of the conference took care of the expenses he incurred incident to the work. Even the invitations from the President to attend the general conference carried each its two-cent stamp! Generous contributions from well-wishers made possible the printing of the various reports.

"This task that you have come here to perform," said the President in his opening address to the conference, "has never been done before. These problems are not easily answered, they reach the very root of our national life. . . . There has not been before the summation of knowledge and experience such as lies before this conference. There has been no period when it could be undertaken with so much experience and background. The nation looks to you to derive from it positive, definite guiding judgments. But greater than facts and the judgments, more fundamental than all, we need the vision and inspired understanding to interpret these facts and put them into practice. . . ."

The facts and judgments presented by the various research committees, and the ways and means proposed to insure their being translated into practice in the homes and communities of America, justify the modest conviction in the minds of the 1,200 members and the 2,000 official delegates and representatives in attendance that the White House Conference on Child Health and Protection was the greatest philanthropic congress of willing workers in the cause of childhood ever assembled on the globe. When made finally available to parents, teachers, social workers, physicians, judges, *et al.*, the reports of the 170 committees will fill some fifty volumes. For four days the beautiful auditoriums of the city of Washington —Constitution Hall, Continental Hall, the Hall of Nations, the Assembly Room of the American Red Cross building, the Corcoran Art Gallery, the auditorium of the National Academy of Sciences, and the auditorium of the Interior Building, not to mention innumerable hotel foyers and dining-halls —were thronged with a multitude of men and women who rank among the leaders in child welfare procedures in this country. The President and Mrs. Hoover opened the White House for a most charming and delightful reception to the delegates.

In attempting to abridge the more important findings and recommendations of the conference, one can but select a few of the high lights. One finds the committee on prenatal and maternal care directing the attention of the conference to the status of the mother before and subsequent to childbirth. Surely it is not an unreasonable recommendation that every woman should be safeguarded during these months by expert care and attention from nurses, dentists and doctors, under the supervision of trained obstetricians, and that in every home and in every hospital this care should be available whether in rural or urban communities, and for all racial, economic and social groups. Our mortality rates from accidents and complications of child-birth are still shockingly and inexcusably high. As a nation, we have barely even made a beginning of safeguarding the mother during pregnancy. Only a small portion of women receive adequate prenatal, maternal and post-natal care. Many practical nurses are ignorant, untrained and a menace to both mother and child, although it is also a fact that some practical nurses, self-taught as they are, are capable and efficient in their work, and have had considerable experience in their communities. The mid-wives as a group are far below the standard of Continental mid-wives, as they have always been. In the progressive European countries mid-wives undergo two or three years of training, and are subsequently kept under direct control and supervision of well-trained obstetricians.

The committee on medical care for children finds very little evidence of any great number of parents who see to it that periodic health examinations are made of their children of pre-school and school age. The general practitioners of medicine report parents to be almost universally neglecting this precaution. Here is a situation admittedly greatly in need of remedying. The pre-school years, before the child is brought into contact with the school medical and inspection service, are years in which incipient major defects find footing in the child organism. Diseased tonsils and adenoids, poisons and weakness resulting from the children's diseases, and the ill-effects of poor nutrition run riot in the pre-school period, injuring and slaying here and permanently disabling or debilitating there. Adequate health service would prevent these disastrous losses in the still trackless and uncharted wastes of the pre-school period. While our infant mortality rate has declined gratifyingly in the past fifteen years, it is still higher than it is in New Zealand, Norway, Sweden, Australia, Switzerland, the Netherlands and the Irish Free State. The lowest mortality rate in this country is found among the babes of mothers born in Russia, mostly Russian Jews.

There are in the United States sixteen millions of children under the age of six years, and the committee on the infant and pre-school child points out that these first six years of life remain largely still unchanged. Parents too commonly labor under the conviction that the pre-school child "just grows," and that care of him is largely a matter requiring no particular skill or knowledge. From a fairly wide sampling of the homes of four-year-old children, the committee concludes that physical care is on a more effective level than is training for mental and social adjustment. In fact, it was agreeably surprised to find the physical standards in the families surveyed higher than had been anticipated would be the case. Typically, the four-year-old sleeps eleven and a half hours; drinks from one and a half to two and a half pints of milk a day; has cod-liver oil in winter but not in summer; eats occasionally between meals; is bathed daily in summer and twice a week in winter; owns and uses a tooth-brush; has had a medical examination within a year; is punished by the mother rather than the father; is spanked from one to four times a month; plays out of doors from five to eight hours a day; and the chances are one to three that he has been inoculated for diphtheria, one to four that he has been vaccinated, and about even that he goes once or twice a month to the movies. In few cases does the family have contacts with a social agency, clinic, or public health nurse. The level of practice in matters of health in these homes is related closely to the socio-economic status of the family and to the educational background of the parents. In calling attention to the need of assisting and encouraging parents in the exercise of their educational function, the committee sagely asserts that the parent himself is a teacher as well as a parent, and needs help quite as much as do professional workers with children.

The committee on communicable disease control finds that no fewer than three millions of cases of communicable disease are reported annually in this country. Obviously many more are never reported. A million and a half of these diseases occur in children, and they furnish about 20 per cent. of all deaths. In addition to the fatalities, blindness, damaged hearts, weakened kidneys and many other disabilities follow typically in train after an epidemic of the children's diseases. Infantile paralysis and tuberculosis together succeed in crippling from a half to three fourths of the whole group of cripples. The time is not long past—indeed is not yet entirely past—when mothers were heard to say: "I want my Tom to catch measles and scarlet fever and chickenpox and all the rest, while they are going the rounds. I don't want him to grow up and have to get them then!" These diseases have recognized and high mortality rates, and are followed so frequently by very serious complications that it is in the interest of economic and humanitarian motives that the periodic sway of the communicable diseases shall be speedily broken. Isolation and quarantine have failed, partly because the real mischief has been done before the first cases in a community are recognized clinically, and partly because the public has been disappointingly indifferent to the rigorous acceptance of the regulations. Through a wider extension of public health nursing into home, health center and school; through prompt reporting, adequate isolation, adequate hospitalization, prompt investigation and control of carriers; and through consistent education of the community, very much can be done to improve conditions. Such a program will mean well-trained, full-time health service for federal, state, urban and rural units, with proper assistance whenever and wherever needful. This is neither impractical nor unrealizable for every community in the land.

The committee on milk production and control finds that every man, woman and child in the United States consumes on the average a little more than one pint of milk a day throughout the year, and that this amount is slowly increasing though it is still well below the optimum. As a nation, we are far from being as insistent in our demands for pure, pasteurized milk as we are in some localities. Surveys made in 430 American cities indicate that the quality of retail raw milk tends to improve as the size of the city increases. In the five-year period from 1924 to 1929 there occurred 258 outbreaks of communicable diseases that were traced to contaminated milk, with some 11,000 individual cases and 371 deaths. Two thirds of these epidemics were of typhoid fever. The incidence of these outbreaks occurring in small country towns, rural sections and cities under 35,000 population, was much higher than in the larger cities. Fluid milk is still a strong offender in the transmission of disease, due to inadequate public health supervision of the milk supply which aggregated, in 1926, more than 15 billions of gallons for the whole country. For these reasons it is imperative that the coordinated attention of all state and local agencies, including public health authorities, agricultural departments, and agricultural, extensional and educational organizations within the state or community, shall be given to all factors relating to the sanitary production and distribution of this most universal and essential of all foods.

Is family life in America threatened? This is a query raised by the committee on the family and parent education. The thesis is suggested and defended that machine-age culture is not inimical to the evolution and enjoyment of the best of family values. It is patent that many transformations are being wrought in the family by our industrial civilization. In an age of specialization, increased technology is diminishing the satisfactions and the interest in work. Thus the stability of employment is affected adversely. Factories are drawing workers from the rural and settling them in the urban communities. Child-less marriages become more common and the percentage of homes owned by their occupants diminishes with urban living. Single-family dwellings decrease and tenement and apartment dwellings increase. The ratio of married women gainfully employed outside the home is raised markedly in such circumstances. Illegitimate births and divorces increase with the size of the community. Buying the living has replaced producing it in the home. Other results of this change in our fundamental social organization include the location of homes around factories, less space per person, less privacy, less play-room, less family entertaining, more dependence upon outside sources of amusement, less real family life.

Notwithstanding these circumstances, it would be fairly easy to make use of the changing economic factors actually to strengthen the bonds of the family, if society were to vouchsafe as much time and deliberation to the study of the situation as it is willing to employ in the solution of other important economic difficulties, such, for example, as those touching trade, the exchange of commodities and the like. It is possible—indeed, the reasonable standards are known already—to set up enlightened standards of housing; to encourage and stimulate wide home ownership; to provide safe and attractive recreative centers and opportunities; to establish and guarantee the continuance, with rational safeguards, of a reasonable income that shall be sufficient to maintain the family in comfort and contentment; to provide medical and nursing service that is not prohibitive; and to better adjust the home and extra-home activities. The time is adjudged right for laying the foundations of a new science of the family. To this, the findings of home economics, sociology and of child psychology and mental hygiene can contribute tremendously. Parent education becomes of supreme importance in any such new science of the family, and such agencies as churches, religious and lay educational organizations, community centers, health clinics, visiting nurses, social workers and visiting teachers, may be expected to assume large importance in acquainting parents with the needs and potentialities of their children and of the family life together.

The family is basal to civilization. None of its inherent functions can safely be removed from it. Whenever outside influences appear to be endangering them or it, there is instinctive resistance. For parents there is no substitute. It is through them and his contacts with the family that the child finds security, love and protection. Well-adjusted parents are essential in providing him with a wholesome emotional background. At its best, the home serves to transmit culture, aesthetic tastes and intellectual stimulus. From it the child derives his social insights, his fundamental attitudes and the foundations of religion. To preserve the institution of the home and to dignify and ennoble it must be one of the potent objectives of government and of education.

In its report upon the child of school age, the committee on the school child finds a grimly bright picture in the circumstance that while adult mortality from accidents has increased 32 per cent. within the last seven years, the accident mortality of children has remained stationary in spite of the increase in population. It is a tragic commentary upon our times, however, that in the year 1929 no fewer than 18,000 children were killed in accidents. This was nearly a fifth of all accidental deaths for the period. Strong emphasis is placed by this committee upon the ways and means of promoting both the physical and the mental health of the child in the schoolroom. Obsolete and insanitary buildings are denounced; the future necessity for an all-year program of recreational activities is stressed; the still too common practice of assigning and requiring home-work in the elementary grades is criticized; a summer round-up of all children who are to be school entrants in the fall is called for; systematic and effective health inspection is recommended; Schicking and vaccinating before school is demanded; the importance of correction of juvenile defects whenever they appear is emphasized; and a thorough-going system of health teaching and physical education is outlined in detail. A somewhat new note in education is the insistence by this committee that mental health is quite as important as physical health, and that the attiutdes which a child develops toward his work, his studies, his mates and associates, his country and society in general, are of profound significance in shaping the effectiveness and the happiness of his life outside of and beyond the school. It is the belief of the committee that teachers must be trained to understand the importance of mental adjustments, and to teach children how to think and work and enjoy and appreciate and judge and sympathize and respect and wonder and reverence, quite as well as to multiply and parse.

The committee on vocational guidance finds plenty in our industrial system, as it affects young workers, to criticize and condemn. Blinded by the spectacle of the upper few in our schools who go on to secondary and higher schools, society has failed quite generally to take note of the millions of children who leave school at the expiration of the compulsory period to enter workaday life in the thousands of occupations. Contrary to the recommendations of physicians that no gainful junior employment can be safely begun under sixteen years, and to the growing opinion of employers that eighteen years is a better minimal age, hundreds of thousands of boys and girls under 16 continue to be employed in a great variety of non-agricultural occupations, chiefly in factories. Many of the types of work into which these children enter are physically and morally detrimental and are fraught with high prospect of accident hazard. The length of the factory day for 14- and 15-year-old children is very often fifty or more hours a week, and the wage invariably averages under $15.00 and generally under $10.00. More than 20,000 minors under the age of 18 are injured annually in hazardous occupations. In 13 states, 1,100 were killed or disabled permanently in industry within a single year. More child workers are engaged in agriculture than in all other occupations, many of them being either hired out, or else migrant workers with their parents under a contract system. In this type of employment, work is hard, hours are long, exposure to dampness and cold is frequent, the cramping positions in which plastic bodies must be maintained over long periods are fatiguing and deforming, and the rights of formal schooling are seriously infringed upon.

The whole question of vocational guidance and protection from exploitation in the occupations is greatly in need of solution. Testing; counselling; exploratory study of the occupations; revision of the school curricula, in junior and senior high schools, to include guidance; study of occupations in all continuation schools; the devising of placement and supervision machinery for young workers; and the making available of scholarships and aids for keeping boys and girls of needy families in school—these are among the recommendations made by the committee. The needs of such vocational education and counselling are not yet widely enough appreciated by the general public, which is not fully aware of the far-reaching changes in our industrial system that have been recently coming to pass. Among these changes are the following, every one of which indicates the distinct necessity for preparatory adjustment in the worker before he enters it: new machine methods of production and distribution; increased mechanization of even the simplest manufacturing process; the introduction of the automatic telephone, telegraph, bookkeeping and billing machines and tabulators; self-service restaurants; power-driven farm machines, etc., etc.

In the matter of protecting children from exploitation, progress has been very uneven. Some states have developed high standards of protection for juveniles; others have been content to maintain low standards. Children in the latter sort of state are denied equality of opportunity for health, education and play. In the former type, the manufacturer must compete with the products of cheaper labor in the latter type. The whole problem is greatly aggravated by the extreme mobility of our modern citizenry, which results in the migration of workers from low-standard communities into communities possessing high standards, thus hampering civic and economic progress. True democracy can not be realized until every one has a fair chance, a good start and an equal opportunity. The institution of child labor denies all three of these boons to the children of the poor.

The committee on recreation and physical education finds that, barring practice in a very few nursery schools, there is almost no attention being yet vouchsafed to the younger child along the line of physical education and constructive recreation. Though the pupil of school age is somewhat better provided for than his younger brother, he is still too largely neglected. Only a few states permit the use of school grounds after school hours. Many school sites are being continually encroached upon by the ever-expanding industrialism which raises the value of land and so reduces the size of playgrounds and school yards. Innumerable buildings in our cities have no school grounds worthy the name. Conditions in many non-urban districts are only slightly better. There is little organization of recreational activities; little curricular time devoted to them; little stimulus to a permanent interest in them, and little attempt made to provide desirable coaching and training through the wise classification of pupils according to their specific needs or defects. It should be deemed to be as proper and inherent a function of the school to promote normal physical growth and structural development, neuro-muscular coordination, emotional expression and control, love for and increasing skill in physical culture and activities, and such desirable character traits as modesty, fairness, generosity and loyalty, as to promote knowledge and facility in the conventional school subjects. An enlightened and adequate system of physical education and recreational development must be the proper channel through which to bring these things into being. Fortunately there are many agencies outside the school—private and semi-public—that are supplementing this program. Scouting, summer camps, clubs, associations, community centers and the like are rendering invaluable service in this field. One of the major needs in the building and administering of programs in recreation and physical culture is that of trained leadership. Another, equally important, is that of educating the public generally in the significance and in the objectives of this program.

The committee on special classes desires to disillusion those smug individuals who consider specialized education of the handicapped an educational frill, or a charity, and not a sound public policy. Rather, it is a most sound policy, for by training these unfortunates, society is making them both self-supporting and self-respecting. In one state, the amount earned by the disabled in the first year after vocational rehabilitation was introduced, over and above that earned in the preceding year, was five times the total cost of the rehabilitation. It is even sounder economy to train the handicapped child than it is the handicapped adult, for he is more plastic and will respond more promptly. The handicapped children in the United States include, among others: 14,000 blind; 50,000 partially blind; 18,000 deaf; 342,000 with hearing impaired to such an extent that they should be taught lip-reading; 1,000,000 with defective speech; 300,000 crippled, and 450,000 mentally retarded enrolled in elementary grades, of whom only 60,000 are in special classes. Most of the 3,000,000 elementary school children who need special class opportunities are still herded in with the rest of the school population, with undifferentiated types of study and work. Such special classes as exist are limited chiefly to the cities, and to only a few of them. In the smaller communities and rural districts this problem has hardly yet been even touched. Guidance of an exploratory or prevocational sort, of which these child types stand so sadly in need, is the very common exception everywhere. These children—especially the mentally slow—idle or fret along at tasks which they can not assimilate, and develop as by-products of their failure mental attitudes of resentment, inferiority, stubbornness and often rebellion. They are doomed by the very nature of their deficiencies to be failures in the conventional classroom; in a special classroom most of them will succeed gratifyingly. Far from being foreordained, this tragedy of failure is preventable.

The gifted children, of whom there are a million and a half in the schools of the United States, present another phase of the same problem. Left in the conventional classroom, they stagnate, lose interest, develop slothful habits and attitudes, and may end by dropping out of school prematurely as cynics and malcontents. Many gifted persons, it should be recalled, are in our penitentiaries; many more of them are in the community, employing their talents selfishly or actually detrimentally to the common good. Yet it is the gifted few who must be counted on to supply our inventions, manage our great enterprises, create our art and literature, conserve and control our wealth. It is the height of social and economic folly to miss-fire in our handling and training of the more gifted among the rising generation, forcing them thus into selfish and anti-social fields instead of enlisting them perennially on the side of human welfare and progress.

The committee on youth outside the home and school presents, among many interesting and valuable findings, none more so than those concerned with commercialized amusements in their effects upon juveniles. The drabness of the adult worker's life in an ultra-machine age leads him to seek "lively" amusement as a reaction to the monotony of the working hours. The motion picture, our fourth largest business, has become within the brief space of a single generation the chief means of recreation. Two billions of dollars are invested in the industry in the United States, and the output of positive film reaches a billion feet per annum. This is 85 per cent. of the world's production! The daily clearance of film through the various exchanges in this country would encircle the entire globe. The 22,600 exhibiting theaters have a seating capacity of 11,300,000 persons. Every man, woman and child in the United States on the average attends a moving picture performance once a week. This is almost half the entire world audience of 250 millions of people a week. In the general field of commercial amusements, the dominant motive is profit rather than public service. Coney

Island, in New York City, for example, alone entertains more than 20 millions of persons a year. Slightly over half the expenditure for amusements in New York City every year goes to the movies, the theaters, the cabarets and the vaudeville; the other half goes to dance-halls, pool-rooms, amusement parks, carnivals and steamer excursions and the offshoots of these. One finds the promoters of amusement projects in large measure making their own laws and establishing their own standards. These laws and standards are often diametrically opposed to those which parents and the educational world generally are striving to set up and maintain. From 50 per cent. to 75 per cent. of the patrons of these institutions are children and youth drawn from the working-class parents, who obviously have fewest resources within themselves. Children's programs of amusement are still unheard of in most communities. Commercialized amusement resorts are apt to have a fringe of criminal or near-criminal hangers-on—prostitutes, gamblers, dope-fiends, bootleggers and the like. Such potential influences are distinctly dangerous to the rising generation. Exactly what relationship exists between commercialized amusements on the one hand and juvenile delinquency and crime on the other hand, is still largely a matter either of conjecture or of prejudice. The weight of responsible opinion, however, unquestionably assigns a significant positive relationship. One of the reports of the New York crime commission, in setting forth the results of a survey of delinquency in one of the districts in Kings County, asserts that "the low-grade pool-room is the chief hang-out for the crook, and more burglaries among boys between the ages of 16 and 21 are concocted there than in any other single place."

The committee on dependency and neglect, after affirming its faith in the importance of maintaining the dependent child in his own home whenever and wherever possible, presents data to show that, in 1929, 33 states, through mothers' aid legislation, were able to keep 220,000 children, who would otherwise have been placed in foster homes, in their own families, the gross expenditure for this purpose being in excess of 30 millions of dollars. Without this assistance, many a mother would have worn herself out in a desperate effort to earn a livelihood for her children and to keep the home together, paying for this heart-rending labor with later ill-health or break-down, and being conscious throughout the whole trying time that personality and behavior problems were arising in her children for whom no adequate home care and correction could be provided. Supplementing this highly important and economically sound principle of state-aid to widowed or indigent mothers is the work of the voluntary family welfare agencies, which in 1929 provided aid to 380,000 families containing 750,000 children, and of the more than 600 day nurseries of the country which provide daily care for some 25,000 children of working mothers.

The whole problem of dependency involves many complex factors. One has to do with illegitimacy. In the registration area in 1928, 42 states reported 63,942 born out of wedlock. The fate of such children is a hazardous one. Abandoned or renounced by their mothers, spurned by their fathers they become the flotsam and jetsam of almshouses, orphanages and homes. Unmarried parents should be required to assume their responsibilities just the same as married parents, although marriage and cohabitation may not always or even generally be advisable. Another problem concerns itself with the Negro children, among whom the death rate is ⅔ above that for white children. A whole series of problems revolves about the status and efficiency of the child protection agencies, of which there are some four hundred in the United States. In the majority of these, protection of animals as well as of children is championed, and the attention to the former is apt to be more assiduous than that to the latter. The staffs of most of these agencies are small, untrained and inexperienced; consequently only a modicum of constructive child welfare work can be done. The staggering totals in our annual industrial accident column present another factor which bears very directly upon dependency, since accidents are likely either temporarily or permanently to remove the breadwinner from the family. On the whole, while there has been declination in some industries, there has been an increase both in the number and severity of accidents in industry, not to mention the absolutely unjustifiable and needless increase in automobile accidents and fatalities. More than 14 thousand children are orphaned annually through death of their fathers incurred while performing their daily work of earning a livelihood. The workmen's compensation legislation, while affording relief in the amount of 150 millions of dollars annually, fails to protect many thousands of workers whose occupations are not included in the list of eligibility. Among railway employees engaged in interstate commerce, and therefore not eligible, there were 1,700 deaths from accidents in 1927. Among the male population generally, violence (excluding suicide) is the highest single cause of death between the ages of 20 and 55 years. Irregular employment, seasonal unemployment and idleness; displacement of human by the introduction of machine labor, and the improving of technical processes which leaves groups of workers without jobs are other complicating factors in our industrial system, and causative factors in the perpetuation of child dependency and privation. Still another major difficulty is the meagerness of the family income. Recent elaborate and reliable research indicates that an ordinary family, if it is to maintain a reasonable standard of living in an American city of to-day, must have a minimum income of from $1,600.00 to $1,800.00. In 12 industries that employed the largest number of workers in 1929, as covered by the statistics of the United States Bureau of Labor, only three reached or exceeded a minimum wage level of $1,700.00. Two fell below that figure by over $800.00. The committee concludes that "the majority of families in this country are living close to the margin of economic want." Innumerable families are living—or existing—well below this margin, as the experience of hosts of social agencies in our cities abundantly testifies.

The committee on delinquency presents some highly significant food for thought in connection with the age-old but ever new problem of delinquency. The virtue of an adequate system of dealing with the juvenile who has strayed from rectitude lies not in punishing, but rather in understanding the causes and drives that have contributed to the delinquency and in seeking by all known means to remove them. The question of juvenile delinquency is assuming major proportions, the conclusion seeming to be warranted that it has not declined as rapidly and certainly as all our efforts to combat and control it would appear to have warranted. Basally, any delinquent act may be interpreted to be the result of some inner stress or inadequacy to which the victim can not adjust satisfyingly. Some of the causes behind these states of mind include lack of love and understanding in the home; "broken" homes, which are found in one third of all cases of delinquents who come before the courts; gang influences of a destructive nature;

school disinterest and failure, arising out of an educational system that has unfortunately laid more stress upon "informing than forming"; the impossibility which many youthful workers feel of finding pleasurableness and satisfaction in their earning life since so many of the jobs in which they engage are destitute of stimulation and the need for creative imagination; narrow apartment life, with little to commend it to the younger in particular; and the deleterious influence of much of our commercialized recreation, etc. Our treatment of delinquency remains in most quarters obsolete and negative. Police fail to differentiate very sharply between children and adults, employing force and fear rather than intelligence and understanding. Juvenile courts fail largely to diagnose waywardness, and content themselves with maintaining discipline in the junior population. Rehabilitation work is sporadic and inefficient. Probation officers are still not teachers so much as they are officers. Corrective and disciplinary institutions remain even to-day largely places of detention where undisciplined or undisciplinable children and youth may be isolated from the community, notwithstanding the inevitable consequence that such segregation will more likely than not serve to increase the maladjustments between the youthful inmates and the outside world.

Finally, parents themselves will have to learn that after all water can rise no higher than its source, and that to whatever degree deceit, double standards, libertinism, dishonesty, insincerity and sham exist in the parent generation, these evils are bound to be reflected in the conduct and character of the rising generation. In the very expressive words of Judge Cabot: "Guardians of the child have the duty to present in their own lives such patterns of honesty, sincerity and courage as shall challenge the child's emulation. In an age when mechanical devices bring distant wonders and the spread of wealth provides ease and comfort beyond our wildest dreams, it is of the greatest importance that all adults realize that by no trickery is the matter of wholesome life produced. It is only in the example of sincere living that the child finds the dynamic impulse for his own wholesome development."

The White House Conference on Child Health and Protection has delved further into the complex problems of the welfare of childhood in the machine age than any group of investigators has ever before undertaken to do. The findings of the hundreds of experts and specialists who have contributed to it will, within the next quarter of a century, exert a profound influence upon much of our educational and social philosophy. Schools, churches, welfare organizations, jurists, parents, teachers, and all other persons and agencies, who have to do with the care and shaping of childhood and youth, will have at their disposal the basal facts and conditions of child life as they are found to exist at the close of the third decade of the present century. They will have also the counsel and the pooled wisdom of the men of medicine, of hygiene and public health, of education, of psychology, of sociology, to aid them in the planning and in the execution of their gargantuan tasks. The conference itself is over. Back into the far communities of the nation its members and workers have returned, carrying with them a new spirit and a new earnestness. The impetus which their research has given to the cause of childhood, and the momentum which their continued efforts to evangelize their constituencies into the new gospel will gather, will go far toward ameliorating the present not altogether satisfactory status of childhood in the machine age.

SAVE OUR WILD FLOWERS

By Professor EDGAR T. WHERRY

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SUMMER is the time of year when our woods and meadows are gay with wild flowers, at least, *some* of our woods and meadows are. Unfortunately many of them are often raided by people who have driven out from a city or town to spend a day in the country, and others are often swept by fire, started perhaps through carelessness on the part of the same vacationists. The end result is the same—places which should be full of beauty show only devastation and ugliness.

It seems almost impossible to get even well-meaning people to realize how rapidlly the wild plants can be destroyed. There has just come to my desk a copy of a magazine published by an organization devoted to outdoor recreation through mountain climbing and similar activities. Surely, one would think, such an organization should be interested in conservation! Yet the cover illustration shows a couple in a remote mountain meadow, busily engaged in destroying nature's gifts—gathering flowers which could not possibly last until they got them home, but would be sure to wither and be discarded half way down the trail. The comment on this picture in the text reads, "The scenery at this point is one of indescribable grandeur, and tourists made sure to pluck a goodly number of blooming flowers as reminders of their visit." No doubt the flowers were profuse, and it may have seemed as though no harm was being done by the taking of the goodly number which this group of visitors picked; but by the time all the successive groups who go there during the season have picked their goodly numbers, and this is repeated year after year, it will not be long before the place is a barren waste.

The Wild Flower Preservation Society, the American Nature Association and other similar organizations are doing all they can to discourage destructive flower-picking, but public sentiment has not as yet been sufficiently aroused. It will be necessary for every lover of the outdoors to both preach and practice conservation at every opportunity.

One of the most promising plans for saving our wild flowers from complete annihilation consists in arousing the interest of school children in the need for sparing them. There are various ways of accomplishing this, but one of the most successful is to hold contests, in which prizes are offered for the best slogans, or the best posters, which may be used in a campaign for encouraging conservation. The Garden Club of the City of Binghamton, New York, has recently staged such a contest, and an outline of their method of procedure may be helpful in guiding others who may wish to undertake a similar campaign. With the hearty approval of the superintendent of the public school system and of the art supervisor of the schools, a mimeographed announcement was prepared. The contest was opened to pupils of the junior high schools and the seventh and eighth grades of the public schools, and the size of the posters was set at 14 by 22 inches. A list of some forty slogans suggested by the Garden Club was furnished, and the art teachers were asked to guide the children in working out suitable illustrations for these. A period of eight weeks was allowed for the work and a committee of judges was appointed to pass upon the results. One prize of $15 was offered to the seventh and eighth grade school having the best group of 15 posters, and another of like amount to the junior high school having the best group of 20.

The Garden Club Committee saw to it that the local newspapers received weekly notices of the progress of the contest and daily notices after the judging had taken place, and the posters were on exhibition in the public library art gallery and the art rooms of the high school. Illustrations of some of the outstanding posters were then also published and a great many visitors came to see the exhibits. The poster receiving the greatest number of votes for individual excellency showed a tiny tot about to pick a gorgeous red lily, but a gnarled old tree in the background, with irregularities near the base of its trunk forming a grotesque face and two twisted branches simulating arms threateningly outstretched, was saying, "Stop!" The best in the winning grade school collection showed a silhouette of a girl admiring a lovely flower in a meadow, with the legend, "Preserve God's gift—Wild Flowers." The outstanding poster in the prize-winning junior high school set represented a little boy with trowel in hand bending over a group of ladyslipper orchids, but at the base of the sketch were the words "Leave my roots." The contest was formally closed with an evening lecture on wild flowers, illustrated by colored lantern slides, after which the prizes were awarded to children representing the successful schools. But its favorable effects, in arousing in the minds of both the children competing, and the adults reached by the attendant publicity, the idea that our wild flowers need protection, will last for a long time to come.

In addition to the danger of destruction by too extensive picking and uprooting, our wild flowers are constantly subject to the ravages of fire. During the first three weeks of April the newspapers of Philadelphia—in which city this talk is being given—contained reports of nearly four hundred fires in the woods and meadows of nearby parts of Pennsylvania, New Jersey and Maryland. The damage done to the trees, and to structures reached by the flames, amounted to many thousands of dollars; the loss in wild life, while it can not be calculated in money, must have been enormous. All nature-lovers should continually endeavor to arouse public sentiment against setting fires in the woods.

So small, however, is the number of active conservationists, and so large the group of those indifferent or hostile to their ideas, that other methods of saving our rapidly vanishing wild life will also have to be followed. It will be necessary to set aside more wild life preserves, and give them better protection.

During the past few months considerable attention has been directed toward making what is left of the Florida Everglades into a national park. No conservationist who travels far in Florida can fail to be horrified by the utter ruin which has been wreaked on nature in most parts of that state. In the course of a day's drive, one is pretty sure to come upon a dozen areas where forest fires are either actively burning or have recently gone out because there was nothing left to burn. On all sides are seen what were up to a few years ago magnificent hammocks filled with luxuriant tropical vegetation, but are now reduced to groups of pitiful charred stumps. So anything that can be done to save what little natural beauty still remains from complete destruction will be worth while. Personally, however, I am not convinced that it will be desirable to create a national park in the Everglades, because that would mean building an extensive road system there, and the coming in of hordes of tourists, some of whom would be careless with matches; and once a fire is started in the deep humus soil, its extinguishing is a pretty difficult and expensive matter. If any one doubts that fires can do damage in that region, they should look up Small's recent book, "From Eden to Sahara—Florida's tragedy!" In this there are actual photographs, showing how places looked "before and after." And among the areas partially ruined are included the Royal Palm Hammock, purchased a few years ago by the Women's Clubs of Florida and set aside as a state park, but not adequately protected against fire. So I think it would be better to make the Everglades merely a game-refuge, refrain from draining swamps and building roads, and minimize the danger of further destruction.

Considerable newspaper publicity has recently been given to the possibility of saving what is left of the Okefinokee Swamp in southeastern Georgia, and again there is talk of a national park. A congressional committee recently visited that region to look into the possibilities, and photographs taken on the trip have appeared in the rotogravure sections of various newspapers. There are still considerable areas of virgin long-leaf pine and bald-cypress timber left in that region, although these are rapidly being encroached upon by lumber companies. If the only way to save them is to create a national park there, then by all means let us work toward that end. But it will be well to keep in mind the possibility that this area might instead be made a wild life preserve, where its splendid assemblages of native plants and animals can be made the subject of study by naturalists for many years to come.

The Forest Service of the United States Department of Agriculture has recently announced a policy of setting aside within the national forests distinctive areas that will permanently represent the natural forest conditions of all the major forest regions of the United States. Two types are recognized: "Natural Areas," which are to preserve in unmodified condition areas of a hundred acres or so representative of the virgin growth of each forest or range type to the end that its characteristic plant and animal life and soil conditions—the factors influencing its biological complex—shall continue to be available for purposes of science, research and education. And second, "Primitive Areas," in general larger tracts than the preceding, which will consist of outstanding areas of the wilderness type where natural conditions have not been materially altered; their number and location will be determined by public needs, and road and trail development or other improvements will be kept to the minimum necessary for adequate fire protection and administration. This is a splendid step in the right direction; but we need also large numbers of smaller preserves throughout the country.

Some of our states already have extensive park systems, although by no means all state parks function as places of wild life conservation; most of them are of necessity open too freely to public use for that, and with even the best of intentions on the part of visitors, the tramp of a myriad feet during the season will destroy all but the coarser and weedier of the native plants, and send all but the tamest of wild animals scurrying to other haunts. So in addition to state parks we need state wild life preserves, where public use is carefully regulated, but visits by naturalists and teachers are encouraged.

The water supplies of many communities come from springs and streams in restricted areas which must of necessity be protected from the pollution which would inevitably result were the public freely admitted, and such areas seem to be ideal for wild life preserves. I have personally visited but one locality where advantage has been taken of a place of this sort, the wild flower preserve of the Princess Anne Garden Club, in eastern

Virginia. The city of Norfolk has given that club the privilege of occupying a small section of woodland on the shore of one of the lakes which are used as water-supply reservoirs, and this has been surrounded by a high fence, the gate in which is kept locked, and only specially authorized persons hold keys to it. A start has been made in clearing out weedy plants, and in introducing into the area attractive ones which are native to the general region, and a refuge is thus made available for the native species which are disappearing so fast from that part of the country. The great advantage of taking over such a place is that the organization administering it is under no expense for protection, as the city must necessarily maintain guards to keep its water pure. I heartily urge other garden clubs to consider the possibility of taking over such watersheds for wild flower preserves in their communities, and will be glad to learn of the success attained in individual cases.

Before extensive transplanting of wild flowers into such preserves is undertaken, however, some study must be made of the soils existing there, and the requirements of the individual species concerned. There will be no use trying to grow trailing-arbutus or moccasin-flower, for instance, in a patch of neutral or alkaline soil, as such plants are sure to die in a year or two unless an acid-reacting humus soil is provided in the first place, and permanently maintained in that condition. And it will not do to jump at the conclusion that a soil is acid just because moss is growing on the ground, or lots of dead leaves are strewn around. The only way to be certain that the acidity is high enough is to make tests with indicators, that is, dyes which change these colors with different degrees of acidity and alkalinity.

Some provision must also be made to exclude weeds. I once was invited to look at a wild garden which had been laid out on a large estate, at considerable expense, in which, so I was informed, there had been planted hundreds of attractive and delicate spring flowers. When I reached the spot, I saw there a most luxuriant mass of poison ivy, and only after some search was I able to discern a few miserable hepaticas and trilliums fighting a losing battle to maintain themselves. The owner refused to spend the additional sum which would have been necessary to employ a gardener with enough knowledge to keep down the weeds without injuring the introduced native species, and so succeeded only in preserving some plants which needed no protection whatever. Remember that a wild garden must be weeded quite as much as a cultivated one, and count on employing someone sufficiently acquainted with native plants to be able to tell the weeds from the flowers.

Summarizing what I have said in a few words: Every one who loves our wild flowers should do all they can to prevent the unnecessary destruction which is going on all around us. Education will help, but it must be supplemented by the creation of a sufficient number of wild life preserves, both large and small, national and state parks in the few suitable places, but in addition a larger number of smaller areas throughout all parts of the country. Let us all do everything we can to save at least a little of the present natural beauty of our woods and meadows for the enjoyment of future generations.

A MODERN EDUCATIONAL PLANT

By T. SWANN HARDING

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A DISCREETLY anonymous article, "The Lobby We All Support," in the May, 1931, *Nation's Business* brought me up with a sudden start to realize how utterly out of touch with reality in other lines a specialist in one line can be these days. It is very odd, for instance, to observe how a person who is, viewed from the standpoint of education, an officer in charge of the diffusion of knowledge, can become to the business eye a "publicity" and "propaganda" expert with all the invidious shades of meaning those words have recently acquired. That word propaganda, particularly, carries with it a wartime connotation that makes liberals and conservatives alike shudder and feel their pocketbooks.

Not very long ago, Dr. Nicholas Murray Butler wrote, "The extensive and intensive study of natural science, now carried on over more than a full generation, has made no impression whatever upon the public mind. That mind continues to come to its conclusions and to formulate its choices with serene unconcern as to whether any such thing as scientific method exists." Dr. Butler probably exaggerates, it is true, particularly when we consider the advance of scientific methods used by the farmer of to-day, but his statement is worthy of consideration nevertheless. Any modern institution which uses modern methods and modern machinery in the diffusion of knowledge should at least help meet this deficiency.

Years ago the great sociologist, Lester Ward, declared that less than one out of each hundred discoveries of modern science is really understood, or in fact even known about, by one out of every hundred of the general population. Consequently, he argued that our exact scientific knowledge, which gives a new and abiding sense of value and importance to human life in every sphere—not only agriculturally—is just about one ten thousandth useful. In short, we develop just about one hundredth of one per cent. of the potential social utility of science. This is true to some degree in agriculture, where but recently it was authoritatively stated that a lag of 25 years existed between the knowledge of agricultural science in institutions of learning and in the minds of scientists, and its practical utilization on the farm.

That is somewhat the condition information and extension officials confront in the Department of Agriculture. They confront, in the first place, a vast and constantly increasing body of realistic knowledge which is exact, verifiable, demonstrable and communicable. They confront likewise certain practical applications of scientific principles—the motion picture, advertising and the radio, for instance—which, while perhaps developed for other ulterior purposes, have simply inconceivable potentialities as agencies for the diffusion of knowledge. Finally, they confront the problem of so articulating modern mechanisms for the diffusion of knowledge that the facts ascertained by scientists in the Department of Agriculture may be put to work as quickly as possible.

In doing this they find themselves repeatedly criticized as units in a vast bureaucracy which exists for its own self-perpetuation. An officer charged with the duty of making scientific knowledge available and comprehensible to the public may find himself described as a propaganda fanatic—I speak rather generally than specifically here—ever eager to get more money from Congress, to create new jobs, to stalk before the public as a noble benefactor, and senselessly to increase the milling output of "publicity" regardless of the demand for this commodity. So far from reality is this mythical portrait that one wonders by just what qualities of the feverish imagination it becomes possible to paint it.

What are the facts? We live in a democracy which has gone on record in favor of free education. This means that the individuals who make up that democracy will in great measure govern the type of education served to them. It even means that they will, in certain instances, demand the creation of certain bureaus even though government officials in Washington might not prefer to see them created at the moment. For it is a matter of record that numbers of government bureaus have come into existence as a direct result of the insistent demands of citizens who saw the wisdom of research or service in those particular fields. It is also a fact that a bureau is far less likely to come into existence because of the yearning ego of a department official than for any other reason. Indeed on a number of occasions the administration's axe functioned to cut off movements intended to grow into new bureaus.

Furthermore, it must not be overlooked that in building up the scientific staff that necessarily mans a large educational institution like the Department of Agriculture, certain men are appointed because they are specialists and are expected to visualize national needs. Thus it is expected that a soil specialist will focus his attention upon the problem of soil erosion and will, in any way he possibly can, arouse a lethargic public to the necessity of protecting our valuable farm lands.

In a general way, while we have the finest school system existing in any country, these schools, as a whole, do not constitute a great structure planned as the Empire State Building or a battleship is planned. They represent rather a growth like a coral island or like some ramshackle country manor house—an empirical development wherein scrapping and rebuilding have gone on simultaneously. Hallowed and almost impregnable traditions have grown up, among them being the inviolability of the classroom, and so modern mechanisms have fought their way slowly to acceptance. A system of planned education, however, would make use of all modern mechanical and social agencies in a closely integrated manner in order to diffuse knowledge as widely and as quickly as possible. The schools, the research laboratories, the libraries, the museums, the motion picture, the radio and the press would be closely articulated into one functioning mechanism for the spread of knowledge.

It so happens that the United States Department of Agriculture is nothing more nor less than a strictly modern educational plant which has efficiently utilized the latest model mechanisms for educational purposes. It must be viewed as an educational institution. To view it through the eyes of competitive business existing in a profit economy is altogether wrong. Note that I do not say business is wrong. Business has to be what it has to be in this age. What startled me in the article in *Nation's Business* was simply that any one would choose to parody an educational institution in terms of business aims and psychology.

The Department of Agriculture maintains scientific laboratories wherein fundamental research is performed. But it does not intend that this new knowledge, actually created by its experts and therefore its most valuable product, shall be sealed away on shelves from the light of day. Even if it wished to do so the department would not dare hoard the knowledge it develops. If it could not enlist the cooperation of the press and the radio industry in the task of acquainting the public with the results of its activities, other means, which would be far more expensive, would have to be devised.

When a new method is found of eradicating cattle ticks the public is told about it. What possible good could come of spending money to devise means of treating worms in animals, or of conquering contagious abortion or hog cholera or bovine tuberculosis, and then refusing to use any available modern agency to acquaint interested citizens with the fact that this knowledge had been ascertained and was at their disposal? What, indeed, would be the use of hiring a man to work on problems in forestry, to combat plant diseases, or to fight dangerous entomological pests, and then denying him the right of giving wide publicity to the results he has achieved and of seeking to arouse the public to the dangers which inhere in ignoring certain pressing problems?

Hence the Department of Agriculture does not hoard its knowledge. It effects the distribution of its product, if I must use business terms to gain the confidence of business men. It effects this distribution, I venture to say, more efficiently than industry to-day effects the distribution of its products, for every economist will tell you that our system of distribution is not what it should be. The Department of Agriculture accomplishes the distribution of its product, knowledge, by strictly modern means.

It has libraries manned by specialists and ready to serve both those within and outside the department proper. It has, in various bureaus, exhibits which make graphic the findings of the scientists that he who runs may read and learn. It has enlisted the services of the radio and it has done this so effectively that not only do the great commercial broadcasting companies view its programs as an asset so valuable that it is given free time, but public demands expressed in thousands of letters literally compel the department to view educational broadcasting favorably. It has enlisted the services of the motion picture, the educational potentialities of which have seldom been realized. It uses charts and posters extensively. Finally, since it is extremely difficult for the ordinary reporter or free lance writer to interview scientific specialists, and to present the results of those interviews accurately and yet popularly, it maintains a small staff of trained writers who are especially equipped to give the press material it can use already prepared. Aside from this, of course, the department utilizes the printing press itself to the full in the publication of various scientific, technical and popular booklets and periodicals which, again, go out to the public on specific request.

So far as my knowledge extends I believe there is no educational institution in America to-day which utilizes modern means for the diffusion of knowledge so effectively as does the Department of Agriculture. There is no diversity or diffusion of interest here. All—libraries, exhibits, the radio, the motion picture, the newspaper, the printing press—work to one end in closely coordinated fashion. In lieu of public schools the Department of Agriculture maintains, where they are most needed, extension service workers and county agents as local representatives whose business it is to make certain that the department's product, the knowledge of agricultural science, reaches the public, who support its activities, in the best possible manner The system is complete from laboratory to furrow, and it is as impressively modern in its mechanisms as it is complete. To have such an educational organization described in caricature from the standpoint of business ethics is nothing less than startling.

Most criticisms of the federal information services run according to the same formula. First they imply that these services are really "publicity" agencies, in the unfavorable sense of that term. It is then charged or implied that material is put out to advance the interests of bureaus and bureaucrats, rather than the interests of the nation. Legitimate information, scientific and administrative, is supposed to be skilfully adulterated with illegitimate publicity for the benefit of individual government employees or government units. Call a government information service a "publicity agency" and it seems to follow logically that it is up to no good.

Yet is it not proper—is it not socially desirable—to seek publicity for the results of an important scientific project, a quarantine regulation that requires public cooperation, or a plan for bringing about a better adjustment between farm production and market needs? It ought not to be considered objectionable to engage in so-called propaganda for the control of plant or animal pests, the better utilization of land resources, the more efficient use of farm by-products, the protection and conservation of wild life, the use of selected plant seeds or strains of livestock, or the better handling of food products. Only on topics of this sort does the department engage in "propaganda."

By the law creating the department, the organization is required to collect and *diffuse* useful agricultural information. From the beginning, Congress placed informational work in the department on a par with its research work. Only to the extent that knowledge gained in the department is applied in agriculture and industry is the institution justified. In a sense, the total activities of the department must culminate in information. The public supports this department in order that it, in turn, may give its results right back to the people who paid for them and who can benefit by them.

If the department ceased issuing information, agricultural markets would be thrown into chaos, progress in farm technique would be retarded, protection for the public against the adulteration of food and drugs would be far less efficient, production in agriculture and industry would be impeded and made more costly, and efficient cooperation between the department's scientific staff and economic groups having a use for scientific knowledge would be impossible. Hazards in aviation would be increased. Ocean navigation would be made more difficult. Warfare against animal diseases and human diseases would be handicapped. Science itself would lack the stimulus that comes from regular inter-communication among groups of scientific workers. Information is the best known means of getting scientific knowledge put into practice.

To issue information via the press, over the radio, by publications, and by means of motion pictures and exhibits is an efficient and relatively inexpensive method of accomplishing the desired results. One guaranty that the material issued is rightly adapted to its purpose is the fact that it must pass a very rigorous censorship. Press releases have no chance with the average newspaper editor unless they contain important information concisely written. Newspaper editors themselves would be the first to condemn such material if it were purely propagandistic for purposes of promoting bureaucracy. Instead, editors find that the department supplies them with accurate material it is desirable for their readers to have. Radio material must undergo the exacting requirements of radio listeners. Only information that has genuine public interest is acceptable to the press and the radio.

The radio activities of the department

cost less than $35,000 annually. The stations donate their time and it is certain they would not do this unless their listeners were being properly and usefully served. By radio about five million people are reached daily! Press work costs about $50,000 a year and publications cost $950,000. As previously mentioned, this nation is dedicated to a system of free education for farmers. If it be wrong—if it be socially undesirable—to spend slightly more than a million dollars annually to keep farmers and others advised of the most recent triumphs of science, of the daily markets, and so on, then it is equally wrong to provide free education by the Land Grant Colleges. That this philosophy of free education should be changed —and articles like that in *Nation's Business* really so contend—is rather revolutionary doctrine.

The anonymous author of "The Lobby We All Support" is astonished that the Department of Agriculture issues nearly 25,000,000 copies of its publications annually. These publications are not foisted upon persons who do not desire them. Ninety per cent. are actually mailed in response to direct requests. The department receives nearly 300,000 letters a year from interested listeners to its educational radio programs. If public appreciation is any criterion of the value of the department's informational services, the matter is beyond doubt.

It is unfortunate that attacks like those contained in the article, "The Lobby We All Support," should be published in responsible magazines because they are directed essentially not at the government's informational activities, but at the scientific and service functions with which the information work deals. This follows from the impossibility, at any rate in so far as the Department of Agriculture is concerned, of separating its research and service work from its informational work.

If the department's basic activities are justified and if the government is justified in helping American agriculture, all means legitimately employed to give the results of the work to the public are justified likewise. If, in spreading useful knowledge, this department issued only technical monographs, it might escape more easily the darts of the "publicity" critics. Under such circumstances the public would wait years for others to take these monographs, interpret them, and finally diffuse their valuable contributions to practical knowledge. In trying to make this useful material quickly available in a modern manner to every one who can use it, it is inevitable that occasional ridicule should greet it.

The point really at issue is whether the citizen's contributions to his government in the form of taxes should be used for socially beneficial ends or not. An obsolete theory of government held that taxes were well spent provided the general public derived no direct benefit therefrom, and dubbed as "paternalistic" and "un-American" all efforts of the government to perform functional services which, while necessary, are in the very nature of the case immediately unprofitable—the activities of the Weather Bureau are an excellent example. To-day in the Department of Agriculture we have a very modern educational plant thoroughly equipped to discover new knowledge and to diffuse it. Is such a plant socially justifiable? If its research activities are justifiable has it any right to diffuse, by the best means at hand, the knowledge it has discovered? Is it likely that any enlightened person would answer these two questions in the negative?

SCIENTIFIC EMINENCE AND CHURCH MEMBERSHIP

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It is difficult to treat religion and religious issues in an impersonal, dispassionate manner. Any attempt to discuss present-day creeds upon any basis is likely to be interpreted as a direct result of deep-seated and inescapable prejudices. Comparisons of church activities often prove invidious, because the person making the comparisons is incapable of assuming an objective attitude. The resultant lack of impartiality reveals itself clearly in the numerous present-day discussions of vital issues pertaining to religion. Not only is there the difficulty contingent upon the attitude of the individual who discusses religion; there exists also an almost insurmountable hindrance which is the result of the attitude of persons who hear or read religious material. There is perhaps no type of presentation more subject to misunderstanding and misinterpretation. Nevertheless, it appears imperative that all available data relating to religion and its effect upon conduct be scrutinized frankly and objectively.

In *School and Society,* for September 24, 1927, Professor W. S. Ament presented data regarding the relationship existing between church membership, education and distinction. In this article, Ament reported that, in proportion to number, the somewhat liberal religious sects have supplied many more individuals in "Who's Who" than have the less liberal ones.

> On the basis of these figures a Unitarian has 222.7 times the chances of a Catholic of appearing in "Who's Who" (1) (p. 401).

> . . . the Congregationalists supply 27 scientists to 2 for the Catholics, a proportional advantage of about 108 times in favor of the "independents" as they were once called (1) (p. 402).

Ament's study was actuated in part by a notation of C. C. Little in *Scribner's Magazine* for November, 1926. Little stated that there was need for data showing whether any relationship existed between success in intellectual endeavor and liberality in religious thinking. Ament estimated success in intellectual endeavor by the relatively crude criterion: inclusion in "Who's Who." The study is therefore merely suggestive of the true relationship between success in intellectual work and liberality in thinking.

It is of course well known that a name may be included in "Who's Who" for many reasons. Thus, many names are placed in this volume because of successful political activity, and because of numerous other types of non-intellectual achievement. It is true of course that inclusion in "Who's Who" is sometimes indicative of notable success in tasks really intellectual in nature. In other instances, however, selection is due merely to the fact that the individual in question has been elected, or appointed, to an office that theoretically *should* be occupied by a person of ability; *e.g.,* successful political candidates in the United States often do not appear to possess intelligence of a high order.

Many opportunists, other than politicians, are included in "Who's Who." A random sampling of individuals in these enviable pages is likely to include therefore a miscellany of the intelligent and the unintelligent. The writers felt that of all in "Who's Who," the outstanding scientists are most likely to represent the intelligent men of America. This delimitation is somewhat arbitrary, and it appears to restrict intelligent activity solely to the endeavor of the scientist. Obviously, intelligence is reflected in numerous types of work other than science. Nevertheless, intelligence (as adaptive behavior) is undoubtedly clearly and unmistakably reflected in the work of the eminent scientist. Therefore, the writers have studied a particular aspect of religious activity among recognized men of science. This paper presents the frequency with which outstanding scientists are associated with various churches.

The data regarding church affiliation were secured from the 1926–1927 edition of "Who's Who in America." In providing biographical data for this volume, the candidates are asked to report "Religious denomination (if any)." The names of the scientists were secured from the 1927 edition of "American Men of Science," the biographical directory edited by Professor Cattell. This volume contains biographical information regarding approximately 13,500 individuals in the United States who have carried on research in the natural and exact sciences. Of these workers, those who have achieved notable success in their particular fields are identified by means of asterisks.

To identify the eminent in science (for the first two editions of "American Men of Science") ten scholarly representatives of each science were asked to arrange the names of the students of that science in order of merit. The average of these ranks was considered by Cattell to be a fairly accurate index of merit, and asterisks were assigned about 10 per cent. of each group of scientists.

The procedure employed for preparing the 1927 edition may best be described by illustration of how the leading psychologists were selected. Each of the 48 psychologists whose names were included in the first two editions was asked to submit the names of 10 other individuals whose work in psychology seemed to warrant their inclusion in the directory. Those who received 2 or more nominations were asked to propose 10 additional names. The 52 who received the largest number of citations were added to the original 48 to form a group of 100. These names were then arranged in alphabetical order and sent to each of the 100 with the request that the names of the 50 individuals who had done the most important work in psychology be indicated. By this means Cattell secured the names of approximately 50 psychologists whose work was considered by their contemporaries to be extremely significant.

The foregoing summary should make it perfectly clear that the scientists having asterisks attached to their research in "American Men of Science" were not selected arbitrarily. It should be evident also that the group includes the most distinguished scientists in the United States.

A count was made of the total number of names in "American Men of Science" having asterisks attached to their names. The total number was 1,423. Of the 1,423 names, 14 per cent. were eliminated because they were not included in the 1926–1927 edition of "Who's Who." Three per cent. also were discarded because of incomplete sketches in "Who's Who," the names of the scientists in question being accompanied by little more than a cross-reference to an earlier edition of "Who's Who." In all, 1,189 reasonably complete biographical sketches were found and examined. Of these 1,189 sketches, 303 (25 per cent.) included information regarding church membership, 886 (75 per cent.) did not. It may be inferred either that the 886 scientists, who neglected to state their church membership, belong to no church or that they did not consider the information of sufficient importance to include when they were preparing their biographical sketches. Absent-mindedness and forgetfulness can not be assigned as reasons for this neglect since the questionnaire that is filled out, by all those whose biographical sketches appear in "Who's Who," suggests specifically that "Religious denomination (if any)" be given.

TABLE I

DISTRIBUTION OF CHURCH MEMBERSHIP OF 303 OUTSTANDING SCIENTISTS IN THE 1926–1927 EDITION OF "WHO'S WHO IN AMERICA"

Denomination	Membership number	Percentage distribution
Congregationalist	66	21.78
Presbyterian	61	20.13
Episcopalian	52	17.16
Unitarian	37	12.21
Methodist	31	10.23
Baptist	16	5.28
Protestant (unspecified)	14	4.62
Friends	6	1.98
Disciples	4	1.32
Jewish	4	1.32
Lutheran	4	1.32
Catholic (Roman)	3	.99
Universalist	3	.99
Reformed Dutch	1	.33
Swedenborgian	1	.33
	303	99.99

Table I presents the number and the percentage of the 303 scientists in the various church groups. Table I does not take into account the frequency of church membership of the total adult population of the country. The data are therefore misleading except when they are studied in connection with the data of Table II. Table II gives the frequency of church membership among the entire adult population. If each denomination supplied its proportionate

TABLE II

DISTRIBUTION OF CHURCH MEMBERSHIP IN THE UNITED STATES AS A WHOLE. (DATA COMPILED BY H. K. CARROLL FOR THE *Christian Herald*, 1925, AND TAKEN FROM PAGE 421 OF THE 1927 "WORLD ALMANAC")

Denomination	Membership number	Percentage distribution
Methodist	8,920,190	23.03
Baptist	8,397,914	21.68
Roman Catholic*	8,023,957	20.72
Presbyterian	2,561,986	6.61
Lutheran	2,546,127	6.57
Disciples	1,759,399	4.54
Episcopal	1,164,911	3.01
Congregational	907,583	2.34
Jewish**	714,270	1.84
Dutch Reformed***	127,000	.33
Friends	115,528	.30
Universalist	59,650	.15
Unitarian	58,024	.15
Swedenborgian***	6,363	.02
Other denominations (Est.)	3,367,385	8.69
	38,730,287	99.98

* The Roman Catholic membership of 16,047,914, representing all baptized communicants, and hence approximately the total Catholic population, has been divided by two to place it on about the same basis as the largely adult membership of the Protestant bodies.

** The Jewish total 357,135, representing heads of families, is multiplied by two for a similar reason.

*** Membership totals for the Dutch Reformed and for the Swedenborgian denominations were obtained from the "New International Encyclopaedia," and are estimates of membership in 1915, the latest year for which the writer was able to obtain data.

share of outstanding scientists, the percentage distributions for the denominations in Tables I and II would be parallel and orderly; the church having the largest total membership would supply the largest number of research workers; the denomination having the next largest total membership would furnish the next largest number of research aces, etc. This situation, however, was not found. Some denominations provide a much smaller number of outstanding research workers than one would predict from membership data, and others furnish many more than their expected quotas.

An overview of this situation may best be obtained by inspection of Table III which reveals the extent to which each church group reaches or exceeds its statistical expectation in furnishing research workers. Table III sets forth the proportionate number of eminent scientists furnished by 14 religious denominations. The procedure employed in making Table III follows. In Table I one finds that the Congregationalists supplied 21.78 per cent. of the 303 scientists. Table II shows, however, that the Congregationalists comprise only 2.34 per cent. of the church members of the United States. This means, as shown in Table III, that the Congregationalists supplied 9.30 times as many of the scientists listed in Table I as one would have anticipated from the church membership data. The Unitarians provide 81.400 times their expected quota, the Friends, 6.600, the Episcopalians, 5.701, and the Presbyterian, 2.995 times their quotas. Comment regarding the Swedenborgians and the Universalists is withheld because of the small numbers of cases. All groups, other than those mentioned (and the Dutch Reformed), fall below (some of them conspicuously below) their expected quotas. Table III shows clearly that the Roman Catholics provide the smallest number of research workers in proportion to their number.

TABLE III

Number of Times Each Denomination Reaches, Falls Below, or Exceeds the Quota (Expected from Church Membership Data) among Starred Names in "American Men of Science"

Denomination	Proportional representation
Unitarian	81.400
Swedenborgian (1 member only)	16.500
Congregationalist	9.308
Friends	6.600
Universalist	6.600
Episcopalian	5.701
Presbyterian	3.045
Dutch Reformed (1 member only)	1.000
Jewish	.717
Methodist	.444
Disciples	.291
Baptist	.244
Lutheran	.201
Roman Catholic	.048

Ament reports (for what is undoubtedly a less highly selected group of scientists) that the Congregationalists supply 27 scientists to 2 among the Catholics, a proportion on the basis of membership of about 108 to 1 favoring the Congregationalists. The data in this paper show a proportional advantage in favor of the Congregationalists of 193 to 1! Apparently the proportional advantage in favor of the Congregationalists increases markedly as the group of scientists investigated becomes more highly selected. It is true that Ament's study included data for the several branches of the Catholic church whereas this study treats of Roman Catholics only. This difference, however, does not affect appreciably the foregoing comparison since the Roman Catholic Church includes most of the Catholics of the United States. If this study had presented data for the several branches of the Catholic Church (like Ament's study) the proportional advantages in favor of the Unitarians and the Congregationalists would have been even larger. This is because the three Catholic research aces listed in Table I are all members of the Roman Catholic Church. The other branches of the Catholic Church supplied no research aces.

A comparison of the two extremes in Table III, the Unitarians and the Roman Catholics, reveals striking differences. The Unitarian appears to have 1,695 chances of becoming very distinguished in science to the Roman Catholic's one!

The objection may be advanced by some readers that, since only about one fourth of the outstanding scientists mention their church affiliation, the data are inaccurate for the several groups that contain few eminent research men. In the judgment of the writers there is no justification for this criticism. There is no reason to assume that members of one church group would be decidedly more reluctant to state their church affiliation than would others. Indeed, it seems logical that the less liberal groups would feel obligated to state their church affiliation *somewhat* more frequently than would the more liberal ones. One inescapable conclusion may be drawn from these data. The more liberal denominations provide many more eminent research men than do the less liberal ones. These data corroborate Ament's results from studying "Who's Who."

The writers have commented previously that the non-liberal denominations do not furnish many research workers. By "liberal," the writers imply relative freedom in interpreting biblical pronouncements and flexibility in reacting to questions such as fundamentalism, the Virgin Birth, etc. The Unitarians and the Congregationalists are generally alleged to interpret such matters with relative individual freedom. Many wings of the Methodist and Baptist denominations tend to be uncompromising in their interpretations.

Special comment should be made regarding the Roman Catholics who supply, in proportion to their number, the smallest number of research workers. As employed in this discussion "Roman Catholic" refers to a single religious organization which, in 1927, had a total membership of 16,047,914 in the United States.[1] When this figure is divided by two, it may be compared with the Protestant denomination figures; this division is necessary because the Catholic Church includes many more children than do the Protestant denominations. The comparisons made in this paper followed this liberal allowance. Striking indeed is the fact that three only of the 1,189 eminent scientists report that they belong to the Catholic Church.

Summary and Comment

1. Only about 25 per cent. of the outstanding scientists in America report church affiliation in their biographical sketches in "Who's Who." About 50 per cent. of all individuals whose names appear in "Who's Who" provide this information. Scientists appear in general to attach little importance to this item.

2. The 25 per cent. who give information regarding church affiliation are associated in most instances with the relatively liberal denominations. The Unitarians and the Congregationalists provide strikingly higher percentages of research workers than do the Catholics, the Lutherans and the Baptists.

3. Noticeable indeed is the small frequency of Roman Catholics among the starred names in "American Men of Science." Among 1,189 outstanding scientists, three only report membership in the Catholic Church.

[1] Data taken from the "World Almanac" for 1927, p. 421.

4. The conspicuous dearth of scientists among the Catholics suggests that the tenets of that church are not consonant with scientific endeavor. It is true, of course, that strict adherence to many Protestant credos would preclude acceptance of certain principles essential in many types of scientific work. The Protestant is generally acknowledged, however, to be less strict than is the Catholic in adhering to ecclesiastical pronouncement. And certain Protestant churches have so enhanced their concepts that it is possible to be fairly liberal in one's thought and still retain membership in church. Thus, it appears that membership in the Congregational and the Unitarian churches is somewhat consonant with scientific enterprise. Noticeable indeed is the close relationship between the liberality of the church and the number of scientists which it shelters. Nevertheless, it is important to note also that about 75 per cent. of the outstanding scientists do not claim affiliation with any church. It is possible that this finding is due in part to the fact that science is a very jealous mistress. Possibly the outstanding scientist is an individual who so busies himself with his studies that he neglects not only church activities but also fraternal, philanthropic, political and social enterprises. The foregoing hypothesis may account in part for the fact that relatively few eminent scientists report church membership, but obviously this hypothesis can not account for the denominational differences that are here set forth.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

WHAT THE ATOM LOOKS LIKE

By Dr. ARTHUR H. COMPTON

PROFESSOR OF PHYSICS, UNIVERSITY OF CHICAGO

To those of us who work in physical and chemical laboratories atoms become familiar acquaintances. I gave as my subject for this afternoon "What the Atom Looks Like," because I wanted to introduce you to these little friends of ours. First let me show you something that an atom can do. I have here in front of me a little electroscope, connected through an amplifier to a loud speaker. My watch has a luminous dial, which has in it a weak preparation of radium. I shall take off the crystal from the face and hold the watch close to the electroscope. Do you hear the "plops" coming from the loud speaker? Remove my watch and the "plops" cease. Repeating the experiment, I find that the face of my watch must be within about two inches of the electroscope before more sounds are heard. What causes the sounds? Evidently something shot from the radium in the watch face. But what are these somethings? Let us call them "alpha particles" for want of a better name.

Lord Rutherford once caught a lot of these alpha particles to see what they made when there were enough of them. He compressed some radioactive gas into a glass tube with walls so thin that the alpha particles would pass right through. After a few days he noticed gas collecting in the space surrounding this tube. On passing an electric discharge through this accumulated gas, and looking at it through a spectroscope, he saw the brilliant colors characteristic of the gas helium. Thus he showed that the things that make these plops, when a speck of radium is brought close to the electroscope, are bits of helium shot from the radium.

Many of you know the romance of helium. Observed many years ago by Lockyer in the spectrum of the sun, it remained unknown on the earth for a generation until Rayleigh and Ramsay, making a precise measurement of the density of the nitrogen in the air, found it different from the nitrogen prepared in the laboratory. Search for the cause of the discrepancy revealed a whole series of new gases—argon with which our incandescent lamps are filled, neon with which we advertise our wares in blazing red, helium with which we now fill our dirigibles, and two others, krypton and xenon, which are now of great value in certain laboratory experiments. Thus was helium found, and now we hear it being formed—the birth of helium atoms. For these alpha particles are none other than atoms of helium gas.

Imagine that by means of such an electroscope as this we have thus counted all the atoms of helium that came through the walls of Rutherford's glass tube, and made the gas that he observed in his spectroscope. How many atoms would we have? In a small thimble filled with helium at atmospheric pressure, the number of atoms is about 1 with nineteen ciphers after it. Perhaps that doesn't mean much to you. Let me put it this way. Two thousand years ago Julius Caesar gave a dying gasp, "Et tu, Brute?" In the intervening millenniums the molecules of air that he breathed out with that cry have been blown around the world in ocean storms, washed with rains, warmed by the sunshine, and dispersed to the ends of the earth. Of course only a very small fraction of these molecules are now in this room; but at your next breath each of you will probably inhale half a dozen or so of the molecules of Caesar's last breath.

Molecules and atoms are very tiny things; but there are so many of them that they make up the world in which we live. I wish there were time to tell you about the remarkable experiments that have shown the parts of atoms. There are some hundreds of different kinds of atoms, which make up this wonderful world of ours; but all these atoms are made of two more fundamental elements, known as protons and electrons. Hydrogen, the simplest atom of all, has one proton and four electrons. The proton and two of the electrons are concentrated in a tiny nucleus at the center of the atom, and the other two electrons buzz around the nucleus, forming a kind of atmosphere. And so on for the heavier atoms, until we get to uranium, the heaviest of all, which has 92 electrons in its atmosphere.

How the Atom is Built

Old Ptolemy, the ancient Greek astronomer, knew that there was a sun and a moon, the earth and the planets; but he didn't know what the solar system is. When Copernicus and Galileo showed, however, that there is a sun, around which revolve planets in definite orbits, then men felt that they had become acquainted with their world. So, though we have found the parts of which the atom is made, we really don't know the atom until we know how these parts are put together.

Perhaps the best way to find out how something is made is to look at it. If it is like a watch, which we can hold in our hands, this is comparatively easy. If it is the cell structure of a muscle that we wish to examine, we put it under a microscope. But some things are too small to see even in a microscope. By using ultra-violet light of wave-length shorter than ordinary light, we can photograph such things as typhoid bacilli with increased sharpness. But atoms are too small even for this. Now x-rays have a wave-length only a ten thousandth that of light, and if we could use them in a microscope it should be possible for us to observe even the tiny atoms. Unfortunately, we can not make lenses that will refract x-rays, and even if we could our eyes are not sensitive to x-rays. So it would seem that we shall never be able to see an atom directly. It is, nevertheless, possible in the laboratory to get by more roundabout methods precisely the same information about an atom that we should if we could look at it with an x-ray microscope. I have spent a large part of the last sixteen years trying to find what the atom looks like, and it has become something of a game with me.

Last summer, while spending a brief vacation in northern Michigan, I noticed a diffuse ring, not very large, around the moon. Half an hour later the ring was perceptibly smaller, and within an hour we came in out of the rain. This ring was due to the diffraction of the moonlight by tiny water droplets that were beginning to form a cloud. The size of the ring depends upon the size of the water drops—if the drops are small, the ring is big, and *vice versa*. So when the ring grew smaller, it meant that the drops were growing larger. Soon they would fall as rain.

Our method of studying atoms is very similar to this method of finding the size of the droplets in a cloud. Instead of the moon we use an x-ray tube, and in place of the cloud of water droplets we use the atoms in air or helium. For the wave-length of the x-rays bears about the same ratio to the size of a helium atom that a light wave bears to a droplet of water in a fog. The helium atoms spread the x-rays into a halo in just the same way that the water droplets diffract the moonlight. Likewise now, from the diameter of this halo, we can estimate the size of the helium atom. We can in fact tell almost as much about its appearance as if the atom were under an x-ray microscope. When looked at by such an x-ray microscope the atom looks like a fuzzy ball. If this ball is to appear the size of a baseball, we shall, however, have to use such a magnification that a marble would appear as big as the earth.

In the middle of this fuzzy ball somewhere is the nucleus of the helium atom, which has in it the protons. This cloudlike atmosphere is due to the electrons. We commented a few minutes ago that the atmosphere of the helium atom has only two electrons in it. You may wonder how with only two electrons the atom can seem so diffuse. Did you ever see the boys on the Fourth of July waving the sparklers to make circles or figure eights? Of course the sparklers weren't in the form of circles; they appeared that way because they moved so fast. So here, the electrons give this continuous, diffuse appearance to the atom because they are now here and now there, and we have caught a "time-exposure" of their average positions. This is of course what we would see if we could really look at the atom.

There have been fifty-seven varieties of atomic theories proposed. Lord Kelvin thought the atom was something like a smoke ring; J. J. Thomson said it was a sphere of jelly. Rutherford called it a miniature solar system, while Bohr and Sommerfeld calculated precisely the orbits of the planetary electrons revolving about the central nucleus. Lewis and Langmuir objected, and said the atom is a cube. Not, so, it's a tetrahedron, claimed Landé. "Quite a mistake, it's a diffuse atmosphere of electricity around a central core," says Schroedinger. "Only it isn't diffuse electricity," complains Heisenberg, "It's electrons moving now here, now there, which make up this atmosphere." Thus the debate was waged. Now that we see how it looks we find that they were all wrong except Heisenberg. He seems at last to have predicted correctly what we should find.

THE DISTANCES OF OUR NEARER STARS

By Dr. JOHN A. MILLER

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FINDING the size of the universe is one of the most intriguing problems of physical science. Interest in it became particularly acute in the sixteenth century. Copernicus had presented his system of the world. He had asserted, contrary to the tenets of the church and teachings of all philosophy, that the earth revolved around the sun. Granting his thesis, it followed that we should be able to observe the parallax of stars, from which we could find their distance from us. The great Danish astronomer, Tycho Brahe, lived in the last half of the sixteenth century. Though armed with instruments of then unequaled accuracy, which he used with then unequaled skill, he failed to find the distance from us of any body outside the solar system, and on this basis repudiated the theory of Copernicus.

Following Tycho Brahe, generation after generation of men attacked the problem. By-products of their researches richly repaid this expenditure of effort. But nearly three hundred years passed before a single parallax was found. In December, 1838, Bessel, a German astronomer, announced that he had found the parallax of 61 Cygni, a star in the constellation of the Swan, and in January, 1839, Henderson, of Edinburgh, announced that he had found the distance of Alpha Centauri, a bright star in the southern heavens. It turned out that this star is nearer us than any other star whose distance we have found.

The theory underlying the determination of the distances of the nearer stars is simple. It is that of triangulation; it employs the same principle that a surveyor uses to find the distance from his instrument to a point which he can not reach but can see. The astronomical problem is this. On some date, say June 1, the observer draws a line joining the earth and the star, measures the angle between that line and a line joining the earth and the sun. Then on December 1, six months later, when the earth is 186,000,000 miles from the first position, he repeats this process. He then has three parts of his triangle, the two angles he has measured and the distance 186,000,000 miles. From these data he can compute all other angles and sides. He is chiefly interested in the angle at the star, one half the value of which is called the "parallax" of the star. After this has been computed the distance of the star from the sun may be found. This method of determining stellar distances is called the trigonometric method, because it employs the principles of trigonometry. It is a fundamental method, for most other distance determinations rest directly on results obtained in this way. Pursuing the same method, astronomers from 1840 until 1910 determined the distances of 360 stars.

In practice the method is less simple than the description leads one to believe. All the stars are so far away that the triangle we draw is a very slender one. The angle at the star is very small and the farther away the star is, the smaller the angle. How small this angle is, one may realize if he draws two lines from the center of his watch dial to eleven and twelve o'clock, respectively. The angle between these lines is 30 degrees. The largest angle at the star that has ever been found is 1.5 seconds, or about one seventy-five thousandth of 30 degrees. So a very slight error in the measures may become a considerable part of the quantity we are seeking. Therefore the question—How reliable are these determinations of distances?—is frequently asked not only by the layman, but most anxiously by the observers themselves.

The unit of stellar distance most commonly used is called a light year. Every one will recall that light travels with a velocity of 186,000 miles per second. A light year is the number of miles that light travels in a year which is approximately six million million miles—six followed by twelve ciphers. Alpha Centauri, our nearest star, is 4.3 light years distance, or 4.3 times six million million miles. In 1910 Kapteyn, the great Dutch astronomer, assembled and published a list of 360 stars, for which he believed reliable distances had been determined. It was the net result of the labor of parallax observers for seventy years.

New types of inquiry as to stellar properties and behavior, such as their motions, their brightness, mass, density and other things, had evolved many formulae, many of which contained the distance of the star as a variable or parameter. This made it perfectly clear that astronomical progress demanded a substantial addition to Kapteyn's table. Moreover, it was evident that this increment should include stars of various properties, such as spectral type, motions, etc., and that, if possible, the quality of our knowledge should be improved. Experience had shown that distances found by use of the photographic plate were of a higher degree of precision than those found by the older method.

Led by Dr. Frank Schlesinger, then of Yerkes Observatory, American astronomers inaugurated an intensive parallax campaign. Seven observatories in the United States participated and are now participating in this campaign. The work was for several years under the direction of a committee of the American Astronomical Society. By inter-agreement certain lists of stars were observed by all the participating observatories in order to weed out "systematic" errors. Certain other lists were observed by two or three observers. The intercomparisons led to greater refinement, and it is not too much to say that the exactness of our knowledge of stellar distances has been enhanced more than 100 per cent. in a quarter of a century. Certain European observatories have carried parallax programs also, notably the Royal Observatory at Greenwich, which has confined its efforts to the north polar regions.

We know now the distance of four thousand stars with a reasonable degree of accuracy. The trigonometric method is limited (because of the slender triangle) to distances not exceeding three hundred light years. I believe that most astronomers would agree that for stars not more distant than two hundred light years, the trigonometric method is more exact than any other yet devised. But stars situated at a distance of two hundred light years or less form a pitifully small fraction of all those visible in our telescopes.

Knowing the distances of stars enables us to replace conjecture by fact in many lines of inquiry. To illustrate, I shall cite three examples. Men measure the apparent brightness of a star, that is, its brightness as it appears to us. But the apparent brightness of a luminous object depends not only on the actual brightness but also on the distance of the object from us. In fact, the apparent brightness varies inversely as the square of its distance from us. If we could move twice as far from the sun as we now are, it would appear only one fourth as bright. Now we have measured the apparent brightness of many thousand stars, and for those whose distance we know, we can and have computed their actual brightness. The effect has been to make us realize how puny our imaginations have been. We have found beyond peradventure that our sun is hardly an average star, that compared with it there are giant suns, many of them giving thousands of times as much light as it does. Others radiate only a small fraction of that of the sun. The well-known star Canopus in the southern sky is 80,000 times as bright as the sun.

We are curious to know the mass of stars, *i.e.*, how much they weigh. We can answer this very exactly for double stars if we know how far their components appear to be separated, the time they require to revolve around each other, and the distance they are from us. There are 16,000 pairs of double stars known and as years go by each will give up all the data necessary to compute its mass. Then we can tell also for these stars how their actual brightness is related to their masses.

Pease at Mount Wilson Observatory in 1920, using an interferometer invented by Michelson, measured the apparent diameter of the great orange-colored star in the constellation of Orion. It was an astronomic event of transcendent importance. The distance of the star from us had previously been found. It was now easy to compute its diameter in miles. It turned out to be 215,000,000 miles, or 30,000,000 miles greater than the diameter of the earth's orbit. Antares, the bright red star in the summer constellation Scorpio, has a diameter of 400,000,000 miles, while Arcturus is slightly smaller.

There are other methods for obtaining star distances. Using the data collected by the trigonometric parallaxes astronomers have been able to translate into distance certain characteristics of the spectrum of a star. One of these, known as the spectroscopic method, uses the principle that the relative brightness of certain lines of the spectrum varies with the distance of a star from us. By correlating these phenomena for stars whose distance is known with like phenomena in the spectrum of a star whose distance is unknown, Adams and his colleagues have been able to determine star distances. The labor involved is very much less than that of obtaining trigonometric parallaxes and for very distant stars more accurate.

In 1924, Schlesinger published a catalogue giving the distances of all stars whose distances we knew with reasonable accuracy. These distances, in the main, had been determined by the trigonometric method. 1,870 stars were listed. Of these six hundred were nearer than one hundred light years. It is hardly necessary to repeat that we have spoken only of the nearer stars, our next-door neighbors. Most stars are farther from us than that. By indirect methods men have shown quite conclusively that many stars in our local universe are thousands of light years distant and that other universes of stars which we can photograph are thousands of millions of light years away.

MAN'S CONTROL OF HIS OWN DEVELOPMENT

By Dr. OSCAR RIDDLE

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Talking with bees will be a tough job, but easier than a voyage to another planet.—*J. B. S. Haldane.*

Few people have given thought to the possibilities of a real and voluntary control of man's own physical and mental development. Yet the surprising facts which forecast such control would warrant several superlative things. They seem worthy of the skill of a whole city of scientists and of the best efforts of the poets as well. Certainly the outlook in this direction deserves the awakened thoughts of all who love life, since the dignity of life and man becomes greater and sounder once it is proved that man has begun to use his creative power upon his own personality and destiny.

All civilized people now think of it as natural enough that man already has a large measure of control over his own diseases. But the control of such things as stature, color, sex, immunity from disease and temperament are usually not brought by the public into the same picture. The experimental biologist, however, can now place these two sorts of control into essentially the same frame; he can show that there is a fairly close connection between those basic facts which already serve us in the control of disease and those which promise an eventual control of our physical development. Many of the big things concerning disease were learned from the study of lower forms of life—from bacteria to guinea-pig and monkey. These things have been rather easily and rapidly applied to man. Practically all that we know of the control of growth and development has been obtained from the eggs, embryos and young of simpler forms of plant and animal life. Though it is sure that the application of these results to the human will be a long and very tough job, it has become clear that only practical, not natural or theoretical, difficulties have to be overcome; and clear also that many of those difficulties must sooner or later dissolve under the pressure of searching scientific effort.

The control of development of animals and human beings can be approached from two very different sides. The reason we have these two wholly different sets of tools for controlling development is that two wholly different kinds of things are everywhere and necessarily concerned in growth and development. One of these necessary things is a large number of so-called hereditary factors or genes. These genes are substances, doubtless very definite chemical molecules, which are passed on from parent to offspring. Any change which we might make in these hereditary factors would have the great merit of remaining in their changed condition during following generations. In other words, this sort of change—made in a few individuals—could automatically appear later in the thousands of descendants of these few individuals. But the genes are extremely small and the human egg very inaccessible; there is here little hope of our ever being able to pluck out undesirable genes or to invent and insert new ones. The other method of approach is wholly different. It requires no change in the hereditary factors carried by any one. It undertakes to modify or control one or another characteristic through the discovery and control of what is usually called the environment—though, unfortunately, no one has as yet been able to imagine the extreme complexity of that more important part of the environment which is in closest contact with the genes. This method of control would be applied, at least during youth, very much as is medicine and education, to each individual and to each generation.

Though I am certain that the use of the first method, that of controlling the hereditary factors, has an extraordinary value in obtaining the fittest and best agricultural varieties of plants and the most useful types of domestic animals, I am forced to conclude, however reluctantly, that in the case of the human family the control of special environmental factors is by far the more practicable and more useful method; and further, that it is the only method which can extend help and power to all human beings. Let us now mention a few of the notable triumphs of the experimental biologist which lead to this conclusion and which should make it clear to all that this second method of the control of development is of extreme value and consequence to man; this value and effect being parallel to the beneficent effects of the wise and careful cultivation of an agricultural plant.

In one word the laboratories have shown that when we have access to living animal matter that is working very hard and successfully at the job of development—that is, when we examine it in egg, embryo and early life—we find it highly plastic and controllable. Development begins with the egg and the egg develops by dividing itself into two, four and then into thousands of cells all of which unite in the production of a single embryo; but in many cases the experimenter has found that if he, or something else, separates these two or four cells they will each form a separate embryo or animal—two or four animals instead of one. You know also that the egg-cell of most animals or plants develops no embryo at all unless another cell—a pollen grain or sperm cell—unites with it. Experiments on many such eggs have shown, nevertheless, that they can be persuaded to develop in the complete absence of any such male cell. The withdrawal of a little water from the egg, or a little shaking of the egg or still another kind of disturbance, will often cause it to proceed with the whole business of development. Even fatherless frogs have been thus produced. In some simple worm-like animals which can survive being cut into two or more pieces it has been found that, under certain conditions, those cells and tissues which would normally form the tail can be made to reverse their destiny and form a head.

Again, the eye of the frog develops quite like that of the human, and the young tadpole—just like ourselves—uses a bit of his skin for the building of the crystalline lens which lies in the center of his eye. But the experimenter has proved that skin from the back or tail of the tadpole, if transferred to the eye region before the eye is formed, will make just as good an organ of vision as the skin normally used for this purpose.

The color of the skin or hair, at least in some animals, is another thing which may be modified if we very carefully see to it that rather special conditions attend the skin and hair during their growth. One experimenter shaved some of the white hair from the backs of white Russian rabbits, and then kept this bare skin cold while it grew the new hair. These cooled areas of white skin turned black and the hair that grew from them was black hair, not white. This particular and simple method will not bring about a similar color change in all races of rabbits; the kind of genes carried by the race also helps to determine the result. Another experimenter could so graduate a dosage of x-rays on the skin of black mice as to produce white hair, not black.

A certain race of flies bred in a laboratory here in New York were found to have the odd property of developing extra legs—some of them in inconvenient places. It was later discovered that if the eggs and early growth-stages were kept quite warm these would develop into entirely normal flies. Evidently the climate suitable to these flies is the tropics, not New York. Here we see that a special bit of the external environment is sometimes able to correct or to counteract the usual influence of a harmful gene.

It is now known that the sex of many animals is subject to control and reversal. In the oyster the experimenter does not even have to direct this procedure, since it appears that something connected with season readily accomplishes a change in sex. One and the same oyster may be a female this year, a male next year; or perhaps a female in the summer and a male in the autumn. Also in much higher animals, such as birds and frogs, the development of sex has been experimentally changed or reversed. These cases of sex change are of high importance because they have brought with them a new insight into the nature of sex difference, and because they sharply illustrate the control which man has already exercised, in certain favorable instances, over a characteristic which is present in nearly all living things.

It is a great mistake to assume that the qualities possessed by living things are their optimum or best qualities. Two or three instances from animals will show that usual body size is in fact merely stunted growth. It has been shown that the usual growth-rate and size of mice is only half that attained when the young mouse continually gets all the milk it wants. Rats given their full needs of vitamines grow to double the usual size. One type of our white blood cells becomes at least ten times larger when properly fed. The growth of some single-celled organisms can be greatly increased simply by letting some rays of radium play around them. Focusing our view closely upon events and conditions within a little clump of living matter when it is developing most actively—when each hour or minute presents us a different and more advanced animal struggling with the whole of the natural world—we can learn that nature is neither wholly dependable nor beneficent; a controller of environments here faces a wide universe of conditions which may be controlled to the advantage of the organism. Man can not be excluded from the dramatic implications of this statement.

In the plant world, also, development is under similar control. It has been shown that a growing soy-bean can be made to form either of two essentially different mature plants, depending upon the particular rays of light which are permitted to attend its growth. Grown in red-yellow light it becomes a twiner and you regard it as a delicate vine; grown in blue-violet light it is a sturdy shrub. Structure, form, sex, size, color and capability are all things which can be changed in extreme degree through the discovery and use of one or another factor of the internal or external environment.

Our final illustrations of developmental control relate to the very specific substances called hormones. More than a dozen of these powerful products are known to be secreted by the several small glands present in our bodies and in those of all higher animals. Already those little human dwarfs known as cretins are having inches added to their ultimate height, and additional power to their brains, by the use of the hormone prepared from the thyroid gland of the ox or sheep. Another such gland which has a very peculiar importance in the control of our development lies at the base of the brain and is called the pituitary body. One of its secretions, known as the growth hormone, largely decides how tall we are. Much of it means that we become tall; less of it means that we are not so tall. This growth hormone can be taken from ox, sheep or pig and injected into other animals; already used in this way on salamanders, rats and bulldogs it caused these animals to grow to double their normal size. Within a few years this hormone will undoubtedly be purified and then used to increase growth and stature in human beings. And here I hasten to add, in sheer self-defense, that you should not write to me about the possibilities of your lengthening your legs and spine. An earlier experience with a press report suggests to me—perhaps erroneously—that about a third of the human race will be interested in the personal use of this substance. This hormone does not yet exist in a form suitable for human use; just as soon as it is so prepared your physician will know all about it, and he, not I, must guide you—if still young—in your effort to add a cubit or two to your stature.

These few remarks have indicated that the developing individual can be modified by changing either the hereditary factors or the specific conditions under which development is permitted to occur. In the case of man we find our control largely, though by no means solely, limited to a control of an extremely complex environment. In a far deeper sense than now the man of the future must, therefore, become a "maker of environments" in order to control his own structure and capacities to the extent that he has already controlled these same things in plants and in other animals. On some future day all men may have daily before their eyes a few living human examples of man's power to control parts of his own development and destiny; the deeper significance of those examples will then be inescapable and this will bring a lot of mental freedom. That result may be the best of all.

THE LOCOMOTION OF THE SLUG

By Dr. H. A. ALLARD
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THERE are many ways of putting the body in contact with the ground, to accomplish locomotion. Not least interesting among these is the mode of locomotion of slugs. The particular slug which the present discussion deals with is the great slug (*Limax maximus* Linnée).

These slugs introduced from the old world are very numerous in damp, shady localities in the vicinity of man where there is an abundance of vegetation and leaf mould. At night they appear on the walks and leave their queer, persistent footprints as long meandering trails of more or less uniformly spaced viscid spots. When seen in the sunlight at the right angle, these spots reflect the light like thin mica. Fig. 1 shows a photograph of a concrete walk at dawn after these creatures have spent the preceding night trailing over its surface.

It has always been something of a puzzle to me as to how the slugs made these trails as they moved along seemingly so steadily and smoothly, when casually observed. I decided finally to look into the matter and will report my findings.

Since the footprints are circumscribed viscid spots, it is evident that there must be definite points of contact between the body and the walk. This is easily demonstrated by placing the eye close to the walk on one side of the creature and holding a flashlight near it on the other side. Dark shadows demonstrate contact points, with interspaces where the light passes beneath the slug's body.

In order to study some features of its locomotion marks were made on the walk where the contact points were placed beneath the body of the slug, beginning with the first or foremost one at its anterior end.

As the creature moved along, it was noted that the tail in every instance made the last point of contact at each marked point, and here a viscid spot was always left behind as the slug progressed in its locomotion. In each instance the free tip of the posterior between the spots seems gradually shortened until it was brought upon the last spot. At the forward edge of this viscid spot the posterior or tail portion of the body was again made free as far as the hindermost point of contact toward which it was moving.

It is evident that every part of the under surface of the body, from head to tail, serves as a sole or foot, and each point of contact is a footstep, so to speak, upon which the body rests as it moves along. As the anterior portion of the body is advanced beyond the first contact point, the neck is once more lowered and a new point of contact made over which the superstructure of the body proper seems to flow along with such perfect smoothness of progression as to excite wonderment in the observer.

It would appear that the entire under surface of the slug is a big, thick muscular foot or base upon which the body itself seems to be mounted. If a bit of débris to be used as a marker is placed upon the slug's body near the anterior end and at any point from the mid-dorsal line to the edge of the whitish foot, it will be seen that this merely moves along maintaining the same relationship level with respect to the viscid spots beneath, laid down upon the walk. In other words, this demonstrates that we are merely dealing with the body superstructure somehow gliding along in toto, and have not yet seen the true axis and mechanism of its locomotion, which appears to be quite hidden from view beneath the creature's body.

A piece of clear window glass was now interposed in its path, upon which the creature at once climbed. I now removed it to a strong light, and with a hand magnifying glass found it an easy matter to study the creature from all sides. It was not in the least disturbed but moved freely over the smooth glass giving me every opportunity to observe it in the greatest detail. A most interesting feature is revealed. On the smooth glass, the creature appeared to keep its entire foot in close contact with the surface, so that only an unbroken trail of viscid smear was laid down. As it crawled over the glass, the white expanded foot was almost as wide as the body. Along the middle of this was a narrow clearly outlined band extending the length of the slug and comprising about one third of the entire width of the foot. As a creature moved its outstretched body along, a series of light and dark waves passed rapidly, from the tip of the tail to the anterior end, these coming and going in a steady progression toward the head so long as the slug moved. It was at once evident that here lay the secret of the slug's locomotion. So far as I could determine with a small magnifying glass, this narrow central longitudinal axis, the locomotive band, is thrown into a succession of many waves, over which the body superstructure moves along as smoothly as if it were on rollers. As a matter of fact the mode of locomotion seems to be of this order, or perchance can be likened to that of the caterpillar tractor, except that in the case of the slug there is no return of the tread.

A more detailed study was made of the frequency of these waves concerned with the progression of the slug. A space of one inch was marked on a piece of white paper. The hindermost edge of this one inch space was brought even with the tip of the slug's tail, and as the creature moved forward in a direct course, a count was made of the waves passing a point placed a short distance in advance of the front line delimiting the inch space. When the tip of the tail had advanced just to the forward line setting off the inch, the count ceased. Many counts were made in this manner, with the slug moving at various speeds. Twenty-six different counts gave a mean value of 27.4 waves required to allow a progression of one inch distance. This number was closely approximated in nearly all counts as the following data shows:

23	waves	: 2	instances
26	“	: 5	“
27	“	: 3	“
28	“	: 9	“
29	“	: 5	“
30	“	: 2	“
Total...... 714		26	

Mean 27.4 waves.

Since the space traveled is one inch, and 27.4 waves were required to advance the body this distance, we have a forward displacement of the body of .036 inch for each wave.

The speed of a slug is scarcely worthy of emulation by a human, yet speed is merely a relative matter and even the slug has its averages and maximums.

Using a stop watch, counts were made of the time required in traversing a distance of one inch on a clear piece of window glass, these varying in six counts as follows: 20.4 seconds; 14.4 seconds; 12.4 seconds; 15.6 seconds; 12.6 seconds; 18.4 seconds. The maximum and minimum values give respectively distances of 25.5 feet and 17.5 feet per hour. This is in fair agreement with determinations made under normal conditions out-of-doors on a level concrete walk, where one large slug, apparently travelling at the usual speed, covered 14 inches of straight course in five minutes, amounting to a rate of 14 feet an hour.

There is some indication that the mode of locomotion of the slug may be changed depending upon the character of the surface over which it moves. On ordinary

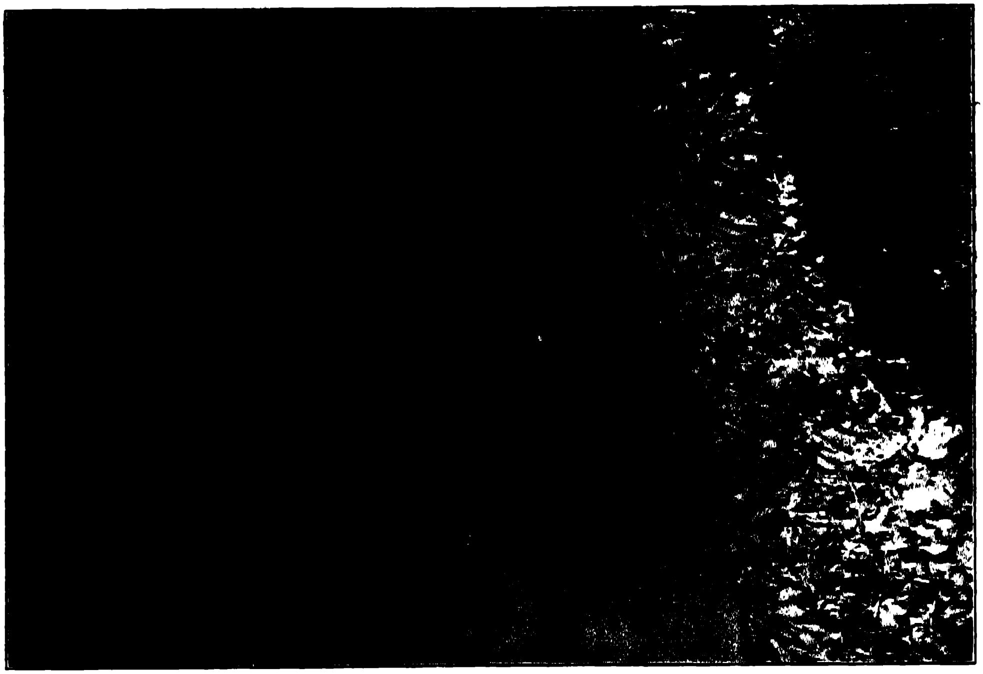

FIG. 1. PHOTOGRAPH OF THE NOCTURNAL TRAILS OF THE SLUG *Limax maximus* UPON A CONCRETE WALK, SHOWING THE SPACED SLIME SPOTS WHICH REPRESENT ITS FOOTPRINTS.

level surfaces such as soil, boards and concrete walks, the creature's usual mode of travel is such as to leave definite viscid *footprints*, so to speak, in a regular linear arrangement. This implies a slight arching of the foot at intervals, enough to keep it free from the surface over which it is traveling, except at the points of contact indicated by the slime spots of its trail. A large slug with its body fully extended 4½ to 5 inches in length may lay down 5 or 6 points of contact. Twenty-two slime spots have been laid down in a distance of 14 inches. In other trails, 18 spots in 15 inches and 12 spots in 8 inches have been counted, giving respectively, 18.8, 14.4 and 18.0 spots per linear foot.

It would appear that this is the usual mode of travel rather than an appressing of the entire length of the foot to the surface. Even when a slug travels up a vertical concrete wall, the trail is marked by spaced slime spots as when a horizontal walk is traversed. On very smooth surfaces such as glass and a glossed paint surface the body appears to be appressed throughout, and the slime trail becomes faint and more or less continuous.

It is possible that reduction in the area of contact of the foot to the surface is an economy in the direction of conserving the slime secretions, since an appreciable amount must be lost in laying it down along any trail. Probably no secretion can be discarded without some cost to the organism. Just what part the slime plays in assisting locomotion is not known, but since every wave passing along the median tread of the foot must be appressed to the fixed points localized beneath its body, it is conceivable that a concentration takes place here, more being needed, perhaps, on certain kinds of surfaces than on others.

Slugs are very restless, active creatures at night and are especially fond of moistened earth and walls where there is a drip of water. In their meandering they readily make their way far up the trunks of trees.

The differentiated central axis of locomotion enables the creature to travel along any surface whatsoever, whether it be horizontal, vertical or even in a completely reversed position beneath a ceiling or well cover. Furthermore it can travel serenely up a fine plant stem, if it chooses, simply by contracting that portion of the foot on either side, so that it closely invests the stem, while the locomotive band or tread proper, with its nicely spaced undulations, carries the body forward on the narrow cylindrical surface. The slug's mode of locomotion is a most interesting and specialized one, with none of the slow, cumbersome, irregular squirms and laborious hitch along of portions of the trailing, rolling body in the manner of the common earth worm. The creature's onward progression is extremely smooth and graceful. A view of its pale whitish foot from beneath, closely appressed to the glass, marked with rhythmic moving waves of light and dark intervals along the median line of the tread, reveals something of impressive beauty and perfection, to offset the rather slimy, repulsive aspect of the lowly creature.

Slugs are voracious and omnivorous feeders. Not only can they be very destructive to green growing plant tissues, but they take readily to diets of bread, potatoes and other table wastes such as are placed in dishes out-of-doors for the cat or dog. I have often seen half a dozen of these creatures congregated in a pan of such food, where it has been set in an open place in a yard. It would seem that the creatures are oriented to these dishes of food by some olfactory sense, since the visual sense can be one only of generalized light sensitivity. As a matter of fact the experiments of Moquin-Tandon and the observations of L. E. Adams in England in 1897 establish this beyond question for *Limax maximus*.

The slug appears to have few enemies owing to the viscid secretions which cover its body. I have seen large ants run up to one, and as quickly rush away as soon as some of the sticky slime became fastened to their feet and antennae. While I have been studying them I have frequently seen minute flying insects and gnats alight upon them and remain helplessly captured, sticking to their slimy secretions until dead.

When all is said, the slug, which so many shun and despise, is a most interesting creature, and would well repay intensive study with respect to the physics of its unique locomotion.

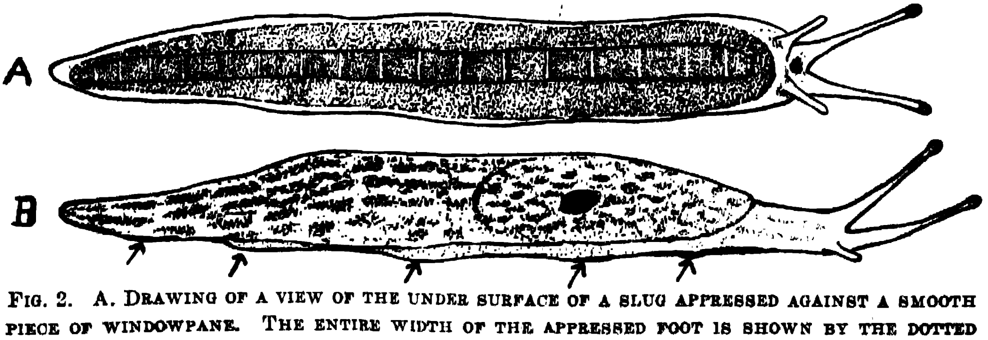

FIG. 2. A. DRAWING OF A VIEW OF THE UNDER SURFACE OF A SLUG APPRESSED AGAINST A SMOOTH PIECE OF WINDOWPANE. THE ENTIRE WIDTH OF THE APPRESSED FOOT IS SHOWN BY THE DOTTED AREA. THE MEDIAN AREA WITH CROSS STRIATIONS REPRESENTS THE LOCOMOTIVE BAND OR TREAD WITH TRAVELING WAVES, THE NARROW CRESTS OF WHICH REFLECT THE LIGHT MORE STRONGLY THAN THE DARKER INTERVENING DEPRESSIONS. B. SIDE VIEW OF CREATURE WITH NECK EXTENDED AND POINTS OF CONTACT OF THE BODY WHERE THE SLIME SPOTS ARE LAID DOWN ALONG ITS TRAIL. THESE SPOTS APPEAR TO DERIVE THEIR SLIME FROM THE NARROW MEDIAN TREAD ALONG WHICH THE WAVES RAPIDLY MOVE. ABOUT NATURAL SIZE.

THE MOUSE-EATING TARANTULA[1]

By PHIL RAU
KIRKWOOD, MO.

A VERY large specimen of tarantula, *Sericoplema rubronitens* Auss. (kindly identified by Mr. Nathan Banks) was brought into the laboratory at Barro Colorado Island in Panama on August 17, 1928, and placed in a wire insect cage.

Remembering Fabre's experiment on the effect of *Lycosa* poison on a small bird, I wished to try the effect of tarantula poison on a small mammal. It so happened that Donato, the caretaker, was about to liberate several small mice which had been kept for other purposes; one of these would nicely serve my purpose.

After permitting the tarantula to fast for two days, an active mouse, whose body length measured two inches, was placed in the cage. The tarantula immediately shrank back from the mouse, and the mouse soon retired to a far corner of the cage. After ten minutes, the mouse stealthily explored the floor of the cage, discovered the hind leg of the tarantula and attempted to nibble at it. Quick as a flash the tarantula veered about and imbedded its fangs in the chin of the mouse. After a momentary struggle, the tarantula had full control of the situation, and blood oozed from the nostrils of the mouse.

The object of the experiment was to find out something of the slow effects of the poison, but in this I was disappointed, for death was immediate. For thirty minutes the victim was held in this manner; occasionally the murderer would remove the fangs for an instant, but soon replace them. Occasionally she would raise herself high on her legs with the fore part of the mouse well off the floor, and walk with it a few inches, and often while she held the mouse with her fangs she would scratch her hairy body with one or the other of her hind legs. And then finally, without removing her fangs from the victim, she carried it to the far corner of the cage and proceeded to enclose it in a silky web. She first attached a broad film of silk to the corner of the cage, and spread it into a mat on the floor by revolving slowly three times; she moved very slowly because she still held the mouse under her body with her fangs thrust into its throat. An hour and a half elapsed after the silk spinning had commenced and she had not yet succeeded in getting it fully encased. She still held the mouse with the same grip on the silken mat, often lifting it high in the air by stretching her legs and moving in circles with it. From this time there was no further effort at silk spinning, but now the fangs moved in and out and I realized that she was imbibing the juices of the limp and motionless body. The work of the poison had been deadly and almost instantaneous.

During the following five hours there was no change; the spider held the mouse quietly on the silken mat and drained the juices. She was not satisfied with fluid nutriment alone, for when I returned to the cage a little later, I found that the skin had been chewed in places and large patches of white flesh protruded. But during all this process, she never once let go of her prey. In fact, when I found it neces-

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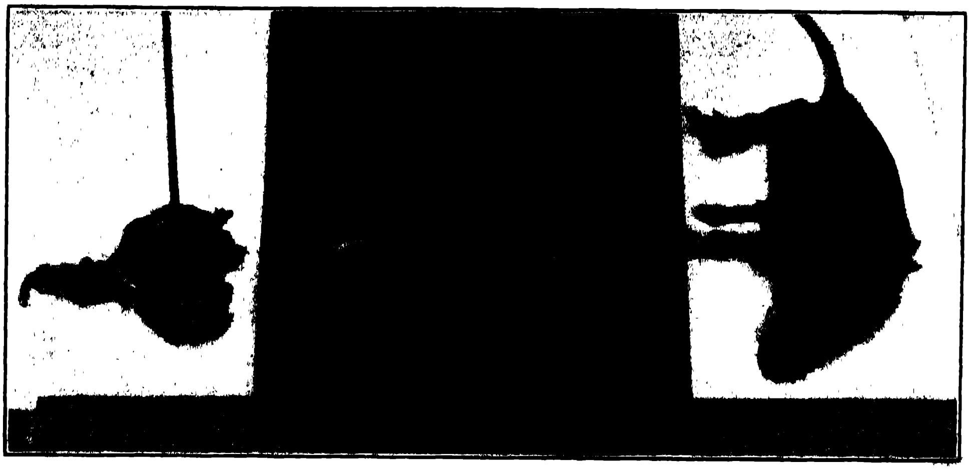
[1] Three very interesting papers by Dr. E. W. Gudger, on spiders and their vertebrate prey, have appeared in *Natural History*, 25: 261–275, 1925; 31: 58–61, 1931; and SCIENTIFIC MONTHLY, 32: 422–433, 1931.



sary to move the cage, she jumped several inches without losing her hold. The enormous strength of the spider was again demonstrated when, a little later, I blew my breath upon her through the screen, she jumped to the opposite wall and climbed its vertical surface for some distance, carrying her burden in the same way.

In the afternoon, the mouse was ill-shapen and much shrunken in size, perhaps one fifth the size that it had been when the attack occurred twelve hours before. I drove her away from it long enough to examine the remains and ascertain that not only were the body juices drained, but the flesh and some of the solider tissues were devoured by this voracious creature. I replaced it, and after twenty minutes she again took up her unsavory morsel, took it to her silky mat and resumed chewing away at the carcass. Thus she continued until midnight. The next morning, in the corner of the cage was a hard, dry mass of skin, hair and bones; this mass, stuck on a pin, is shown at the left of the figure. In twenty-four hours the mouse at the right of the illustration (this was a duplicate of the one used) was reduced to the mass of residue opposite.

One would think that a whole mouse at a meal would suffice for some time, but the next day the tarantula ate several *Orthoptera* also. Thus she was fed on insects from time to time. She was brought to St. Louis in October, and was fed during the winter; however, she ate little but remained active withal, and lived until the following April, withstanding temperature changes in our living-room, which varied from 50 to 80 during the winter.

The large, penetrating jaws are powerful, and I was not surprised when she bit a large hole in the cloth cover of the jar en route home and nearly escaped.

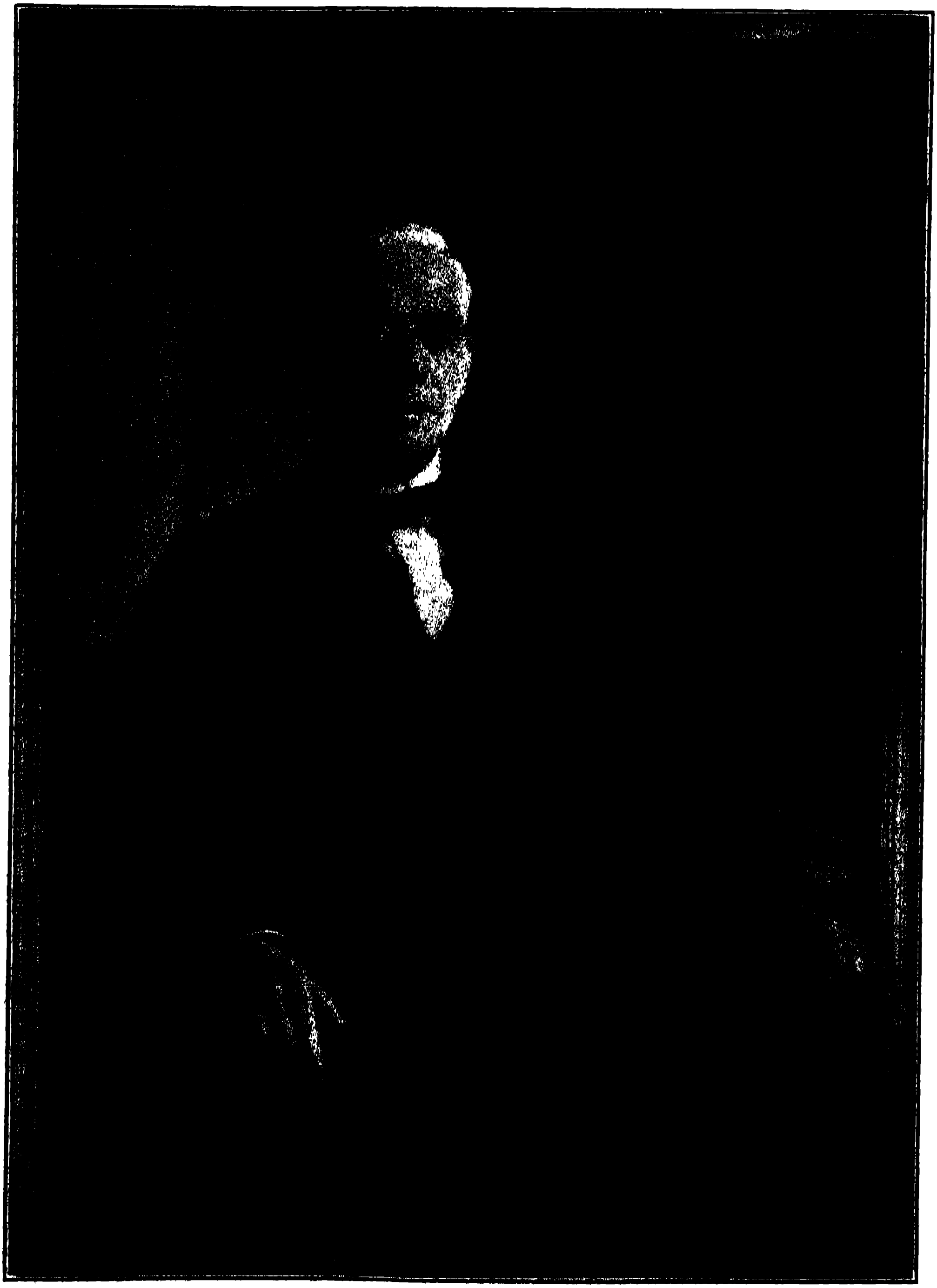
THE PROGRESS OF SCIENCE

HENRY BURCHARD FINE AND THE FINE MEMORIAL HALL

HENRY BURCHARD FINE, born in Chambersburg, Pennsylvania, September 14, 1858, was graduated bachelor of arts, with first honors, by Princeton in 1880. As an undergraduate he specialized in the classics and mathematics, and was one of the small group who discussed philosophy with Dr. McCosh and enjoyed the impulse of his invigorating mind. The year following his graduation he was fellow in experimental science and the next three years tutor in mathematics. Then he went to Leipzig to study under Klein and received his Ph.D. degree in 1885, after which he went to Berlin to be with Kronecker for a semester. He was an ardent admirer of the latter, and returned to Berlin in the summer of 1891 to study with him.

He was appointed assistant professor of mathematics at Princeton in 1885 and professor in 1889. During this period he published several papers dealing with differential equations. He was the author of four books: "The Number System of Algebra Treated Theoretically and Historically" (1891), "A College Algebra" (1905), "Coordinate Geometry" (with Henry Dallas Thompson) (1909) and "Calculus" (1927). The first of these showed the influence of Kronecker; the other three are college text-books. However, the second and fourth are a combination of text-book and treatise, were written with the greatest care, and are notable for their accuracy of statement.

Professor Fine collaborated with Professor Thomas S. Fiske in the establishment, in 1891, of the New York Mathematical Society, which became the American Mathematical Society in 1894. He was a member of the council in the



HENRY BURCHARD FINE

early years of the society and was for many years a frequent attendant at its meetings. He was president of the society in 1911 and 1912.

During Woodrow Wilson's administration at Princeton (1903–1910) Fine was dean of the faculty. These two men had been members of the editorial board of the *Princetonian* in their student days and from that time dates a life-long friendship based upon the respect which each had for the qualities of intellect and character of the other. When President Wilson went to Washington he sought the wisdom and firmness of character of his old friend for several important positions, but Fine decided to stay in Princeton. In the meantime, for the two years before President Hibben was elected, Fine administered the affairs of the university. As dean of the faculty he contributed largely to the raising of academic standards during this period. He was widely recognized as an educator of the best type and declined calls to the presidency of several institutions.

When the preceptorial system of instruction was instituted in 1905 by President Wilson, Fine seized this opportunity for laying the foundations of a department of mathematics of first rank. He was in no hurry to attain his goal. He sought young men of promise and encouraged them in their development, ever impressing them with his high ideals. They were inspired by his revealing talks about the great leaders of the latter part of the nineteenth century whom he knew, such as Klein and Kronecker, and whose great insight he appreciated. When some of his young men, such as Birkhoff, Bliss and Jeans, accepted calls elsewhere he replaced them with younger men of promise. Had not efforts been made to call away members of his group, he would have felt that his policy was not being wisely carried out. The reputation of Princeton as a center for mathematics bears abundant testimony to the wisdom of his plan and of its execution.

Dean Fine's interest in these matters was not confined to his own department. He had an important part in the choice of men in the other fields of science. In 1911 he became in letter what he was in fact—the dean of the departments of science. When it was decided in 1925 to organize a campaign for funds for the further development of research in the sciences, his was the guiding hand and he was the chairman of the committee for this purpose. Years before he had found a kindred spirit in Thomas D. Jones, of Chicago, a graduate of Princeton of the class of 1876, a man strikingly similar to Dean Fine in qualities of intellect and character. As soon as Dean Fine set forth to his friend his ideas for the future of science in Princeton, the latter offered to establish a professorship in mathematics, provided it was called the Henry Burchard Fine Professorship. This was but the beginning. Mr. Jones and his niece, Miss Gwethalyn Jones, gave three other advanced professorships and later he added a fund of five hundred thousand dollars. The fund was completed by other gifts and in particular by one million dollars from the General Education Board, and then Dean Fine was appointed chairman of the committee to advise the president on its administration.

Dean Fine died December 22, 1928, as the result of injuries received the evening previous when he was thrown from his bicycle by an automobile. During the preceding months he had discussed with the members of his department the advisability of a building for mathematics and he had come to feel that it was a necessity for the full fruition of his plans for the department. Immediately after his death Mr. Jones and his niece, who had known of these plans and hopes, announced to President Hibben their desire to provide the building as a memorial to their friend.

Fine Memorial Hall, which was dedicated on October 22, 1931, adjoins and is connected with the Palmer Physical Laboratory. It is built of red brick and limestone in collegiate Gothic style and was designed by Mr. Charles Z. Klauder, of Philadelphia. It is conceived to be a house for mathematics, so that its chief features are the library, studies for members of the staff and advanced students and common rooms. In addition there are two lecture rooms, two seminar rooms and a departmental office.

The library occupies the top floor and is admirably lighted because the building has a central court. It houses the books on mathematics and physics. It is abundantly supplied with tables and chairs. It is the study for the graduate students and each of them is provided with a place for his papers and books. At each corner there is a conference room to which the students may go for discussion of their reading.

The rooms for the staff are not offices but studies. They are comfortably furnished, and as you enter one of them you feel that you are in a home and not in an office building. Some of them are paneled in American oak. Here you will find the private library of the occupant and in most instances a blackboard containing some of his work. Mathematicians take naturally to a blackboard, when they are discussing their problems or thinking them out. Other studies are allotted to advanced students in mathematics or mathematical physics of the type of national research fellows, commonwealth fellows, etc., of whom there are fourteen in residence at present; two of these men share a study.

At one end of the building, on the second floor, there is a room for the members of the staff and at the other end of the building the "Common Room" for teachers and students. These rooms are paneled in English oak, and are comfortably furnished. Every afternoon, about four-thirty, tea is served in the "Common Room." Here one finds those with whom he wishes to confer. Here develops the interest in the things common to the group. Here is the portrait by Mr. Ernest L. Ipsen, of New York, of the man whose hopes and plans are being realized.

This hall has been dedicated to the memory of Henry Burchard Fine. Its solidity of structure, its dignity, its refinement and its sense of calm symbolize the man.

L. P. Eisenhart

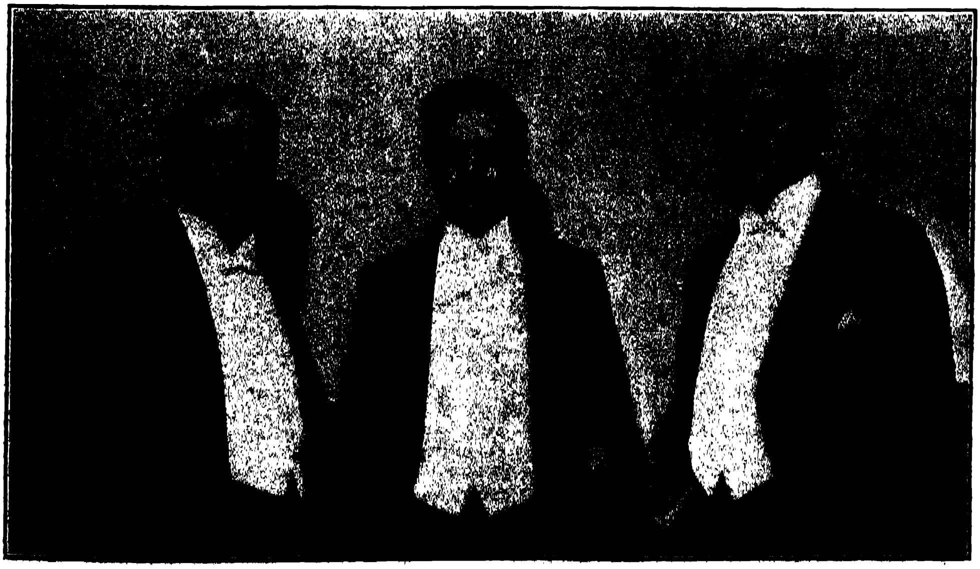
THE LIBRARY IN FINE MEMORIAL HALL

PRESENTATION OF MEDALS BY THE AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS

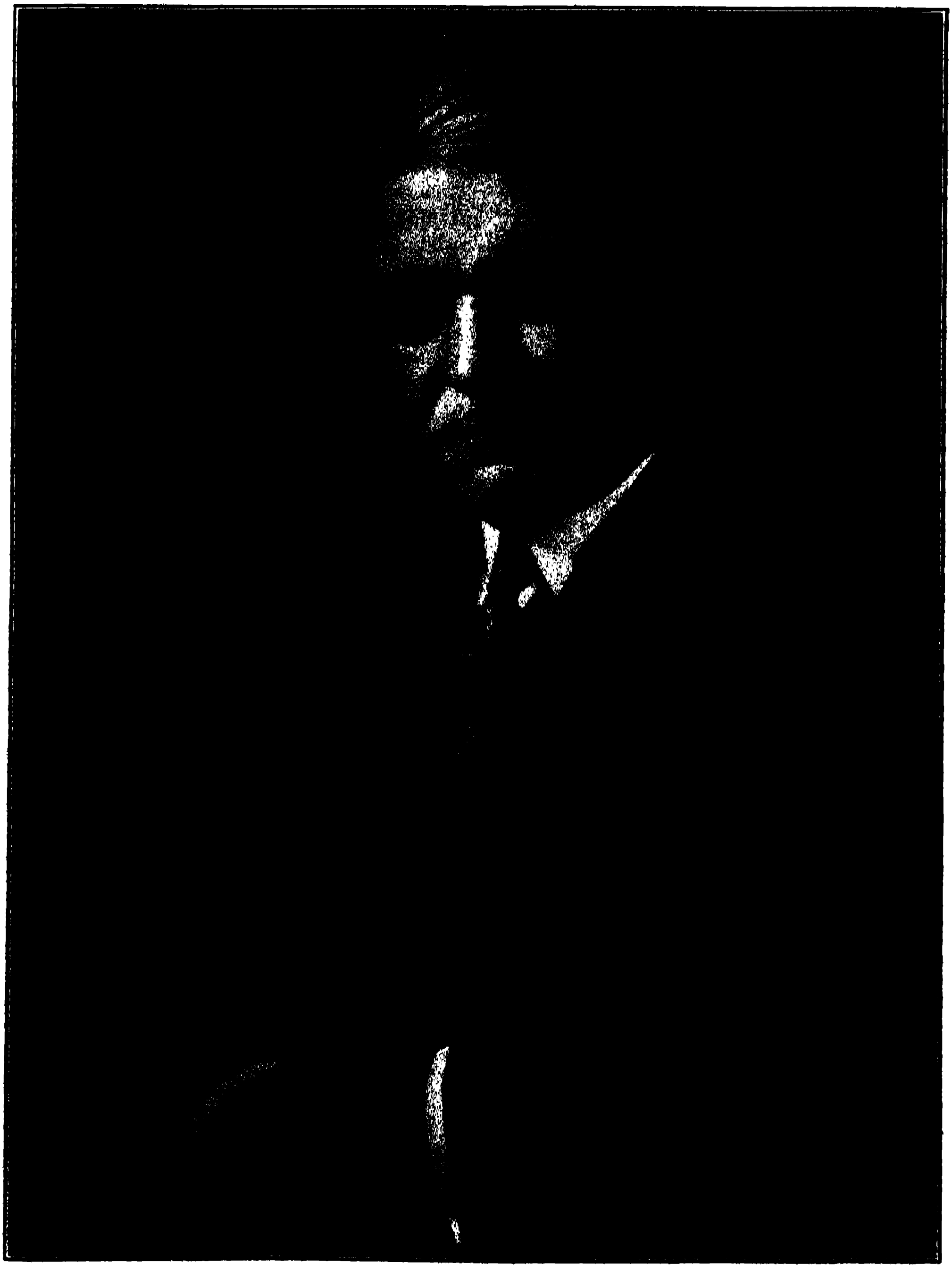
Achievement in the mining of copper ores and in the smelting and refining of copper was recognized at the annual meeting of the American Institute of Mining and Metallurgical Engineers. The William Lawrence Saunders Medal for distinguished achievement in mining was awarded to Francis W. Maclennan, general manager for the Miami Copper Company; and the James Douglas Medal for distinguished achievement in nonferrous metallurgy was awarded to William H. Peirce, president of the Baltimore Copper Smelting & Refining Company and vice-president of the American Smelting & Refining Company.

Mr. Maclennan is a native of Canada and a graduate of McGill University. He has practiced his profession in Canada, Peru and the United States. In 1913 he became mine superintendent for the Miami Copper Company, and since 1919 he has served as general manager. The particular work for which he was cited is the development of a method of mining low-grade copper ore by block caving so efficiently that the over-all cost has been as low as 36 cents per ton of ore. A measure of the success of the operation is the mining of 21 tons of ore per man-shift, a figure never before equalled for underground mining. Previous medalists have been D. W. Brunton, Herbert Hoover, John Hays Hammond and Daniel C. Jackling.

Mr. Peirce, born in Baltimore, was trained as a mechanical engineer. He early entered the copper smelting business and was remarkably successful in the design and improvement of machines and apparatus for the smelting and refining of copper. He has made notable contributions to these arts, his name being known throughout the industry as the co-inventor of the Smith-Peirce basic converter for the production of blister copper from matte.



THE PRESIDENT OF THE INSTITUTE AND THE TWO MEDALISTS
Francis W. Maclennan, Wm. H. Bassett and William H. Peirce.



SAMUEL WESLEY STRATTON

WHO DIED ON OCTOBER 17 IN HIS SEVENTIETH YEAR. HE WAS DIRECTOR OF THE BUREAU OF STANDARDS FROM 1901 TO 1923, AND THEN BECAME PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY UNTIL 1930, WHEN HE WAS MADE CHAIRMAN OF THE CORPORATION OF THE INSTITUTE.

THE AWARD OF THE RESEARCH CORPORATION PRIZES

For effective scientific research, undertaken without thought of personal pecuniary benefit, two scientists—one American, the other Swedish—have each gained the Research Corporation prize of $2,500. It was awarded through the Smithsonian Institution. The men are Dr. Andrew Ellicott Douglass, director of Steward Observatory of the University of Arizona, and Dr. Ernst Antevs, of the University of Stockholm. Each will likewise receive the Research Corporation plaque for their outstanding contributions to science.

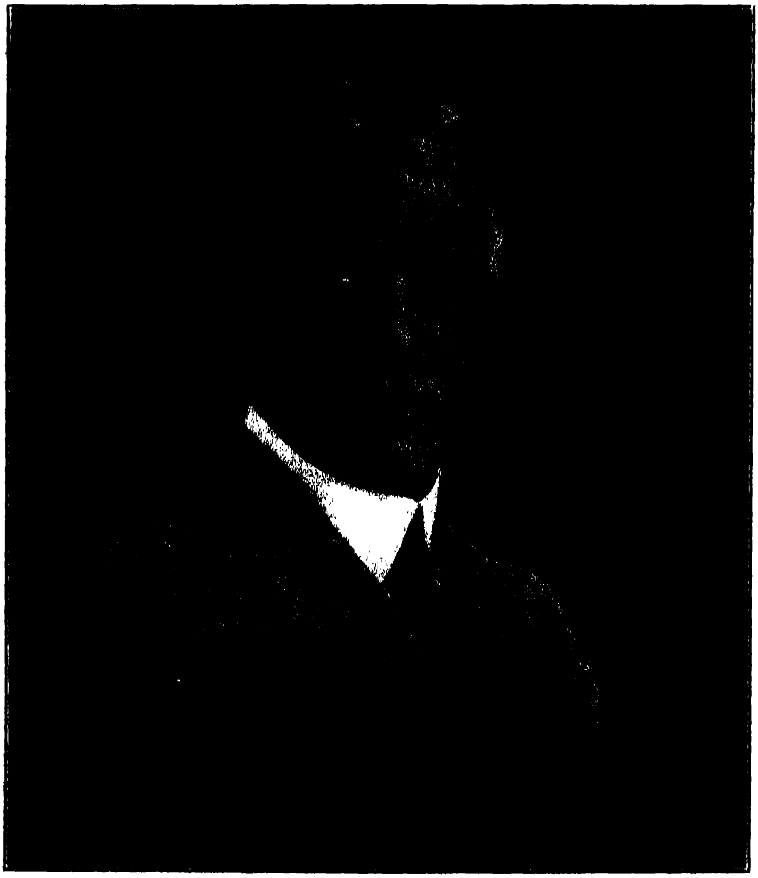
Though in no way related, the achievements of the two prize winners are curiously similar in results and in method; they have succeeded in dating the prehistoric past of the earth by what are unquestionably the two most original and the only exact methods yet developed, and they have reconstructed a picture of the changes in the earth's weather year by year for the thousands of years that they have been able to date.

Dr. Douglass, who is primarily a physicist and an astronomer, used as his chronometer the rings that mark the annual growth of trees. Living amidst the pine forests in the bracing climate of northern Arizona, he was led to think of the connection between climate and tree growth. In 1901 he began collecting records of tree growths as pictured by annual rings in cross-sections of the trunks. A comparison of some 10,000 such records with records of precipitation in northern Arizona showed that the ring formed by a tree each year varies in width in direct proportion to the amount of rainfall. Here, evidently, was an almost infallible record of weather and climate of the region in which the natural chronometer grows. Trees in the same climatic area would show similar response to the same weather conditions in their annual rings; that is, a scale of the proportional widths of the annual rings of one tree for a definite series of years would approximately fit any other tree in the same area for the same series of years. Dr. Douglass found this to be so for trees over fairly wide areas, and this rendered possible their dating on a common scale with practical certainty.

Thanks to this fact, Dr. Douglass has been able to extend back tree growth records in the giant sequoias of California for 3,000 years. He has also connected all the links in the tree growth chain from the present time backward without a gap to 700 A.D. That is, he has created an unbroken annual calendar for that period. Unexpected benefits have resulted from the development of this perfect time scale. Thus, by a study of timbers taken from pueblos built by the prehistoric Indians, Dr. Douglass has been able to give exact dates to events in their history, such as the building of Pueblo Bonito, as far back as the eighth century. There is no reason to suppose that the application of the method can not be carried much farther back in human history.

However, the major fruits of Dr. Douglass' achievements are probably the light they have cast on the past climate of the earth and on the correspondence between weather and solar activity. Dr. Douglass found that trees grown in the wet climates of northern Europe give admirable records of sun-spot numbers; he found several cycles in climate to be multiples or submultiples of the eleven-year sun-spot cycle. This shows indisputably that solar variation exerts a profound influence on weather.

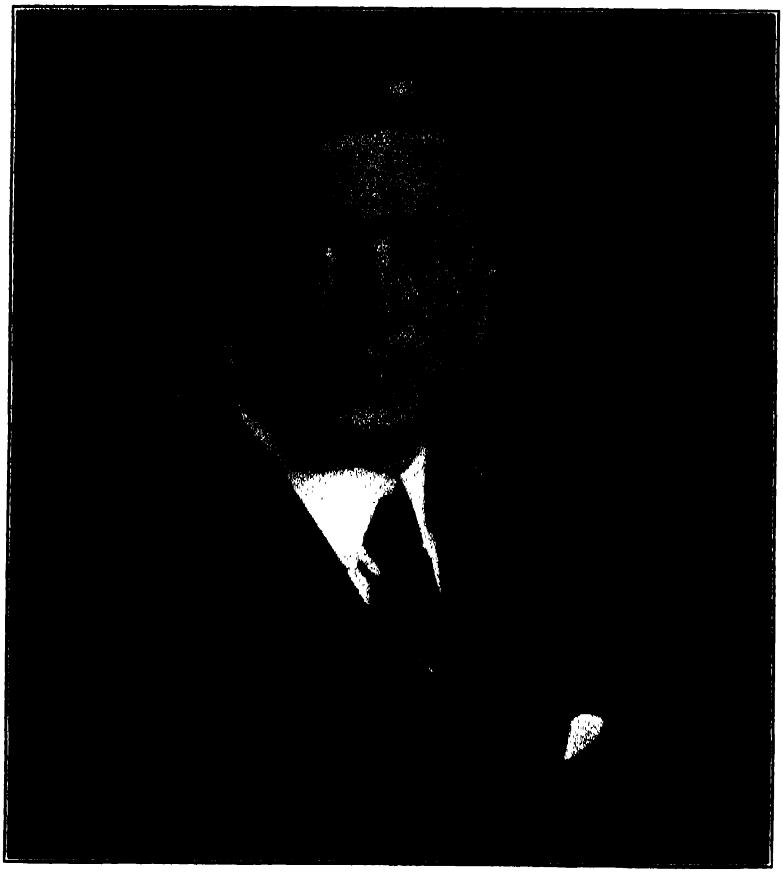
Dr. Antevs used the laminated clay deposits called varves as his time-piece and has traced a series of clay layers up the Connecticut Valley of New England, which mark approximately 4,000 successive years. Dr. Antevs is a pupil of Baron de Geer, student of glacial chro-



DR. ANDREW E. DOUGLASS

nology and founder of the Stockholm Geochronological Institute, and to de Geer belongs the credit for the use of varves as time-pieces of glacial activity.

That nature should have left, and man interpreted, so detailed a record of yearly climates in the soil is no less amazing than the record and interpretation of tree rings. Varves are thin layers of very fine clay which lie one on top of another so that a cross-section of them exposed looks like zebra stripes on the earth. They record the annual erosive influence of melting glacial water. In the Ice Age glaciers of great thickness covered the whole of northern Europe and America as they now cover the peaks of the Alps. When for some reason the earth began receiving more heat from the sun, the latter was able each summer to melt more than the accumulations of the previous winter's snow and ice, and the glaciers began slowly to disappear, retreating to the north and to high altitudes. The melting ice passed through glacial fissures and issued in streams at the bottom of the glaciers, bearing mud and gravel. The finer sediment would be carried farthest—into glacial lakes, where, in the quiet of the following winter, it would settle down into a layer or varve, superposed on that of the previous year. Since the finest particles would stay suspended the longest time, each varve would vary from coarse at the bottom to fine at the top, so



DR. ERNST ANTEVS

that there would be a visible demarcation corresponding to each successive year. Furthermore, the varves varied in thickness from year to year, just as do tree rings, and for comparable reasons. That is, a thick ring would mean a greater supply of water-carrying sediment, and that would mean a hotter summer. In consequence, the thickness of the varves would represent in some measure the power of the sun rays during the summer. As the varves often accumulated to many feet in depth, and as those formed in one lake can be correlated with those formed in another, they constitute a record of thousands of years of solar activity.

Dr. Antevs helped Baron de Geer and other assistants to work out the "Swedish time scale," believed to give approximately in years the time elapsed since the culmination in Sweden of the last Ice Age. In 1920 Antevs accompanied de Geer to America to make a study of American varves with a view to correlating in time American with European glaciation. Antevs has remained in America to become the leading authority on North American glaciation. Besides tracing out a series of clay layers which mark approximately 4,000 successive years up the Connecticut Valley, he has worked out successive positions of the receding ice border, and assigned to each deposit its proper date with reference to a certain point in the glacial period. The measuring of clay layers has been only a small part of his work. As Dr. Goldthwaite, of Dartmouth, says:

> Equally at home in physiography, Pleistocene botany and zoology, and eager in his study of climates of the past, he has never lost sight of the large geologic and geographic problems, such as the registration of changes of temperature and of rainfall by sediments, by tree rings, and by migrations of plants and animals, the nature and cause of crustal warping during the withdrawal of the ice, the emergence and submergence of the coast and of the interior lowlands as a result both of crustal movements and of the exchange of water between ocean and glacier.

The awards to Dr. Douglass and Dr. Antevs are the fourth and fifth of their kind made by the Research Corporation. The first, in 1925, went to Dr. John J. Abel, of the Johns Hopkins University, for his work on ductless glands, animal tissues and fluids. The second, in 1929, went to Dr. Werner Heisenberg, of the University of Leipzig, for his contribution to matrix mechanics and for his exposition of the principle of indeterminance; and the third, also in 1929, to Dr. Bergen Davis, of Columbia University, for the contribution of the Davis double x-ray spectrometer and other brilliant achievements in the field of atomic physics.

The Research Corporation is probably the only organization of its kind in existence. It sprang from the desire of a scientist to have the fruit of his scientific labors capitalized for the promotion of research. In 1911, Dr. Frederick G. Cottrell, then chief physical chemist, later director of the U. S. Bureau of Mines, and his associates offered their invention for the electrical precipitation of suspended particles to the Smithsonian Institution, for the benefit of science. As the institution could not well undertake the development of a matter so likely to have commercial and legal complications, Dr. Charles D. Walcott, then secretary of the Smithsonian, undertook with Dr. Cottrell to enlist the aid of public-spirited men of New York City to organize a non-profit-sharing corporation for the development of the patents, and in 1912 the Research Corporation was formed.

Its purposes are to acquire inventions and patents and make them more available in the arts and industries, while using them as a source of income, and, second, to apply all profits from such use to the advancement of technical and scientific investigation and experimentation. The Research Corporation has succeeded financially so that it has built up a reserve and given large funds to scientific work. Among grants made by the corporation are several to the Smithsonian Institution for work on solar radiation and its influence on plants and animals; to the Kaiser Wilhelm Institute for Medical Research, at Heidelberg, to carry on cancer research, to the International Auxiliary Language Association for linguistic research, to Harvard University, Columbia University, Leland Stanford Junior University, Pennsylvania State College and the Stevens Institute of Technology, in support of various projects. A grant was made to the National Research Council to assist in the publication of one of the volumes of the "International Critical Tables." The last grant has been made to the University of California to make possible the installation of an eighty-five ton magnet, through which it is hoped to produce twenty-five million volt protons.

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